TENTH ANNIVERSARY ISSUE

Radiological Health Data and Reports

VOLUME 11, NUMBER 3

MARCH 1970

(Pages 107–178)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service ● Environmental Health Service

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	$0.386\ nCi/m^2\ (mCi/km^2)$
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	$2.59\ mCi/mi^2$
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 3, March 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and x rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

CONTENTS

Page

A Decade of Publication 107

REPORTS

Results of a Program Directed Toward Reduction of Dental X-ray Exposure 109
Robert B. Rosenthal and *James C. Malcolm*

Survey Results of the Use of X Rays in the Healing Arts Specialties in North Dakota, 1964–1968 117
James A. Kraeger and *Gene A. Christianson*

Strontium and Plutonium Isotopes in Ground Level Air, October 1963–March 1969 129
B. Shleien, J. A. Cochran, and *P. J. Magno*

TECHNICAL NOTES

Lead Content of Glass used for Shielding Television Receiver Components and its Relation to Exposure Rate 135
Harry Levine and *Paul S. Ruggera*

Tritium Concentration in Precipitation, 1967–1968 137
A. A. Moghissi and *C. R. Porter*

DATA

SECTION I. MILK AND FOOD 141

Milk Surveillance, November 1969 141

Food and Diet Surveillance 151

XUM

CONTENTS—continued

	Page
SECTION II. WATER	153
Radioactivity in Florida Waters, 1968	154
SECTION III. AIR AND DEPOSITION	157
Radioactivity in Airborne Particulates and Precipitation	157
1. Radiation Alert Network, November 1969 *PHS*	158
2. Canadian Air and Precipitation Monitoring Program, November 1969	161
3. Mexican Air Monitoring Program, July and August 1969	162
4. Pan American Air Sampling Program, November 1969, *PAHO* and *PHS*	163
SECTION IV. OTHER DATA	165
Offsite Surveillance Around the Nevada Test Site, July–December 1965	165
Strontium-90 in Human Bone, January–March 1969	169
Environmental Levels of Radioactivity at Atomic Energy Commission Installations	171
1. Atomics International, January–June 1969	172
2. Feed Materials Production Center, January–June 1969	175
Reported Nuclear Detonations, February 1970	177
Synopses	iii
Guide for Authors	Inside back cover

RADIOLOGICAL HEALTH DATA AND REPORTS

Published under the direction of

John C. Villforth
Director
Bureau of Radiological Health

Address correspondence to the Editor, *Radiological Health Data and Reports*, Bureau of Radiological Health, 5600 Fisher's Lane, Rockville, Md. 20852.

For subscriptions to *Radiological Health Data and Reports*, please use the order form on last page of this issue.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service ● Bureau of Radiological Health

A DECADE OF PUBLICATION

With this issue, *Radiological Health Data and Reports* marks the completion of ten years of publication. While a ten-year history of publication hardly justifies the issuance of a *festschrift,* it does present a timely opportunity to acknowledge the contributions of the many individuals and agencies whose guidance and efforts helped to establish the publication as an instrument of information on radiation in relation to man's environment. On a more sobering note, the occasion invites an appraisal of past performance and of our responsiveness to changes of emphasis with new directions of public interest.

Radiological Health Data and Reports was established in response to a need to provide information, from a public health-directed source, on levels of radiation to which the population, or population groups, may be exposed. The launching of the publication was given impetus by public concern about the impact of the nuclear age on people's health and well being. Programs that were instituted to assess environmental radioactivity resulting from nuclear weapons tests and other operations involving nuclear energy provided the prime sources of data. In this enterprise, the cooperation of Federal, State, and local governmental agencies, as well as that of various research and educational institutions, played an important role. In particular, grateful acknowledgment is due the Board of Editorial Advisors for its guidance on general policy and their continuing review of content.

Over the years, national concerns in the area of radiological health have undergone changes both in emphasis and scope. As fallout from nuclear testing operations conducted in the 1950's and early 1960's declined, greater emphasis was attached to radioactivity resulting from nuclear power plant and Plowshare program operations. In particular, the importance of machine-produced radiation, especially x rays, received the recognition it deserved. With the passage of Public Law 90–602, the "Radiation Control for Health and Safety Act of 1968," these concerns were extended more widely across the electromagnetic spectrum and even outside the electromagnetic spectrum. As defined in the Act, which relates to electronic product radiation, the term means:

"(A) any ionizing or non-ionizing electromagnetic or particulate radiation, or

"(B) any sonic, infrasonic, or ultrasonic wave, which is emitted from an electronic product as the result of the operation of an electronic circuit in such product . . ."

As information becomes available with respect to the nature and extent of population exposure to such radiation, it is anticipated that reports dealing with the findings will be published in *Radiological Health Data and Reports.* Previous issues have contained reports on emissions of x rays from color television receivers and on the experience of a State following the enactment of a laser registration law. In the current issue, there appear two reports on the results of surveys of x-ray machines and a technical note relating x-ray emissions to the lead content of glass envelopes of color television tubes. The frequency of appearance of reports in these and other areas of electronic products is expected to increase as programs progress.

We look forward to serving the needs of the radiological health community for information in keeping with its broader interests. To the many agencies and individuals whose participation in many capacities made our modest history of publication possible, we offer our deepest thanks. And to all who move with us to meet the future, we express the hope that they will experience the satisfactions that we have enjoyed.

Reports

Results of a Program Directed Toward Reduction of Dental X-ray Exposure

Robert B. Rosenthal and *James C. Malcolm*[1]

X-ray safety surveys in 208 dental offices revealed that almost one million radiographic films were exposed annually. A special study was made of procedural factors affecting roentgen exposure at the cone tip of dental x-ray machines; these were film speed, developing technique, and kilovoltage. Although only 27 percent of the offices were using slow or intermediate speed film, they were found to be responsible for 45 percent of the total cone-tip exposure. A change to faster film reduced their exposure levels by 54 percent. Offices accepting recommended changes in developing technique reduced their exposure levels by 43 percent. The program's effect was an overall exposure reduction of 27 percent. With properly developed fast film, the median exposure levels ranged from 0.19 R/film at 90–100 kVp to 0.62 R/film at 45–55 kVp. The accuracy of electric and electronic timers was also evaluated in selected dental offices.

Special emphasis was placed upon the use of fast film and optimum developing techniques while conducting routine radiation safety surveys of 208 dental offices with 234 x-ray machines, located in two cities in Alameda County, Calif. Data collected on the initial visit provided a projection of almost one million intra-oral films exposed annually, a total cone-tip exposure[2] in the area of 662,000 roentgens per year, averaging approximately 0.67 roentgens per film. This sizeable number of machines offered an opportunity to investigate the relationship of film speed and film processing to cone-tip exposure and a means of finding exposure levels which might be expected at various kilovoltages in offices which develop fast film under near-optimum conditions. It was also decided to record the accuracy of electric and electronic timers.

[1] Mr. Rosenthal is radiation control specialist and Dr. Malcolm is health officer of the Alameda County Health Department, 499 5th Street, Oakland, Calif. 94607.

[2] "Cone-tip exposure" refers to the local roentgen exposure in air at the cone tip. The terms "exposure" and "roentgen" bear the same connotation in this report.

Methods and standards

All basic information was acquired during actual surveys of the offices and by interview with the dentist or his assisting personnel. All units were properly filtered and collimated[3]. The cone-tip exposure was measured with a Victoreen condenser R-meter and 10-R chamber[4]. For use in the followup stages of the program--when survey time permittedinfor--mation was acquired on roentgens per film at reduced exposure settings, either by establishing timer performance with a spinning top timer or by determining actual exposure values at a variety of timer settings.

A small phantom consisting of two human molars and jawbone encased in paraffin was used

[3] As required by the California Radiation Control Regulations, tubes operating up to 70 kVp must have at least 1.5 mm total aluminum equivalent filtration; 2.5 mm is required above 70 kVp. Beam dimension at the cone tip must not exceed 3 inches in diameter. All tubes were found to have circular beams.

[4] In a separate study, it was determined that use of the 10–R chamber with readings in the lower 25 percent of its scale did not introduce any significont error.

to demonstrate that films of high diagnostic quality could be obtained at reduced exposure levels by improvement in exposure and darkroom techniques. When possible, high speed film was demonstrated to users of the slower type film.

Improvement was determined in both of the above parameters by either a followup telephone call or by the use of a reply postcard.

When needed data had not been recorded on the initial visit, a special visit was made if the workload exceeded 75 films per week. The office was excluded from the tabulation when the workloads were small.

In the majority of cases, no followup visit was made to confirm the technique changes reported by the dentist. There is no information on the accuracy of reported improvements or to what degree the new changes were retained. However, in virtually all offices, the dentist accepted the demonstrated improvement as valid.

Film speed

The descriptive term "fast film" refers to Speed Group D, "intermediate" to Speed Group C, and "slow" to Speed Group B-- standards which were established by the ADA Council on Dental Research (*1*). Table 1 is a listing of common brands of film and their several speeds. It is important to note that two intermediate speed films carry the brand description "extra fast."

Table 1. Speeds of common brands of dental film

Manufacturer	Speed of film		
	Slow (speed group B)	Intermediate (speed group C)	Fast (speed group D)
Dupont	D-1		Lightning Fast (LF)
IFI	Blue Hue (BH)	Super Blue Hue (SBH)	Ultra Blue Hue (UBH)
Kodak	Radiatized		Ultra Speed
Minimax		Extra Fast (EF)	Triple X
Rinn	Medium Fast (MF)	Extra Fast (EF)	Super Fast (SF)

Film processing

Processing film according to a specific time-temperature standard is uniformly accepted as the foundation for good diagnostic films. A film is considered to be developed satisfactorily if it is processed at least as long as recommended by the manufacturer for a given temperature. Further exposure reduction is possible by use of "complete" development as shown by the results in table 2 (per manufacturer). The following descriptions are used in discussions:

Sight development ------ any developing without definite time-temperature relationship.

Under development ----- any developing time which is shorter than either of the following

Development per manufacturer -------- based on 4½ minutes at 68°F. (±0.5 minute) or equivalent, with regular dental developer

Complete development -- based on 5 minutes at 70°F. (±0.5 minute) its equivalent or longer, with regular dental developer.

Average roentgens per film

In offices using varying exposure times (or varying kVp's in a limited number of cases) it was necessary to establish an average exposure time from which average roentgens per film could be determined. For this value, a correction factor of 0.87 was applied to the roentgen exposure for a mandibular molar. This value is slightly lower than that derived from Wuehrman and Manson-Hing (*2*) and corresponds to that calculated from the following technique for a full mouth survey:

4 molar films, each 0.5 second exposure
4 bicuspid films, each .4 second exposure
4 cuspid films, each .4 second exposure
2 incisor films, each .3 second exposure
4 bitewing films, each .5 second exposure

The average exposure time is 0.43 second, which is the molar exposure multiplied by the 0.87 factor. No factor is applied to offices employing the same exposure technique on all films.

Results

Film speed and patient exposure

The importance of film speed in relation to exposure levels is demonstrated in table 3. Twenty

Table 2. Exposure reduction through improvement in darkroom technique in offices using fast film (all kilovoltages)

Developing technique	Findings on initial visit				Findings on followup inquiry					
	No. of offices	Films per week	R per week	Average R/film	No. of offices	Films per week	Original R/week	Reduced R/week	Total reduction R/week	Average R/film
Sight	45	3,342	2,058	0.62	29	2,375	1,639	879	760	0.37
Underdevelopment	42	4,645	2,869	.62	27	3,196	2,005	1,183	822	.37
Per manufacturer	36	2,730	1,341	.49	22	1,614	794	466	328	.29
Complete	20	3,578	1,045	.29						
Total	143	14,295	7,313		78	7,185	4,438	2,528	1,910	

percent of the offices used slow film, and although these offices used only 16 percent of the total film, they were responsible for 33 percent of the total x-ray exposure. Sixty-nine percent of the offices used fast film (73 percent of all film used) but were responsible for only 55 percent of the total exposure.

Table 3. Film speed and patient exposure as found on initial visit

	Total	Speed group		
		B Slow	C Intermediate	D Fast
Number of offices using this speed film	208	42	23	143
Percent	100	20	11	69
Films per week	19,641	3,263	2,083	14,295
Percent	100	16	11	73
Total cone tip exposure per week (R)	13,249	4,410	1,526	7,313
Percent	100	33	12	55

Trade names of film resulted in a certain amount of confusion; many users of Rinn and Minimax "Extra Fast" film (both are intermediate, or Speed Group C films) were under the impression that they were using fast film (Speed Group D).

Considerable effort was devoted to inducing users of slow and intermediate film to change to fast film. On followup inquiry it was found that of the 65 offices involved, 15 changed as suggested, for a net reduction of 725 roentgens per week or 54 percent of their previous weekly exposure of 1,331 roentgens. Reductions due to improved development procedures are not included in this calculation.

Efforts to encourage change to faster film encountered resistance due both to personal preferences and to mechanical obstacles. Many users of slow film were older practitioners who felt that this film provided the best in diagnostic value. Some stated that they had tried faster film and did not like it, but whether this reaction resulted from inherent characteristics of the film or from improper processing is not known. In some cases, they were using machines (particularly the General Electric Model CDX and CDX–E) that have no milliampere control and have timers that are unable to make accurate split-second exposures. There was considerable resistance to changing to long cone technique as a means of using fast film. The necessary tool for adjustment of the milliamperage on Ritter B units was acquired in the middle of the program, and the milliamperage was reduced on those units where the dentist was willing to make the change but had a timer which could not perform reliably at the short exposure times required by short cone units.

Table 4 indicates that the use of slow film creates unnecessary patient exposure, even when films are developed according to the manufacturer's standards or longer for a given temperature.

In addition to the obvious fact that the required exposure for slow film is four times that for fast film, this table indicates that although only 13 percent of the offices used slow film (and represented only 7 percent of the total film used), they were responsible for over 23 percent of the total exposure.

Table 4. Average roentgens-per-film at cone tip (all kilovoltages) for films in speed groups B and D (developed "per manufacturer" or better)

Speed group	Number of offices	Films per week	Average R per film	Total R per week
B	15	821	1.34	1,100
D	98	10,763	.33	3,588

Film processing and patient exposure

Whereas less than one third of the offices presented an opportunity to reduce exposures through change in film speed, almost 61 percent were sight

developing or processing film too quickly for a given temperature. Of this 61 percent, over half were sight developing indicating that the majority was completely unaware of any need for a systematic method of film processing.

Table 2 shows the initial findings and progress made in reducing exposures by darkroom techniques in those offices using fast film. It is to be noted that even offices previously developing according to manufacturer's standards were capable of affecting an additional reduction in exposure by suing complete development techniques.

Replies from 20 offices using slow film (1,158 films per week) showed that improvement in darkroom techniques reduced the average exposure from 2.0 R to 1.3 R per film.

Some offices which showed improvement did not necessarily go to complete development. Therefore, in compiling values for net improvement, the offices were grouped into two categories: (1) those sight developing or underdeveloping, and (2) those developing according to manufacturer's standards or completely.

Table 5 shows the effectiveness of placing emphasis on proper darkroom procedures. Responses from dentists showed a doubling of the use of recommended techniques with a resulting 22 percent reduction in total patient exposure.

Table 5. Effects of the survey program on developing technique and patient exposure (all kilovoltages, all speeds of film)

Survey	Percent of 208 offices developing film as recomended	Percent of 19,641 films/week	Percent of weekly exposure	208 offices total weekly exposure
Initial	37	38	29	13,249
Follow-up	73	76	68	10,291

It is evident that with the use of proper darkroom techniques overall exposure is reduced. A doubling of the number of offices and films in this category more than doubled the group's share of population exposure, but the total weekly exposure was reduced by 22 percent. Improvement in darkroom techniques has proved to be the most productive activity within the program, and should result in a benefit to dentists by providing radiographs of superior quality.

A surprising number of offices had no provision for warm running water in the darkroom, a condition not compatible with good processing because ambient temperatures were often below acceptable levels. Many had no running water at all, a deficiency likely to result in incompletely rinsed films and contaminated fixer. A lack of recognition of the direct relationship between exposure and film processing was evident.

No discussion of developing would be complete without mention of the 1-minute developer. The manufacturer of one brand informed us that the "1 minute at 68°F" equals, in terms of net density, conventional processing for 3 minutes at 68°, and that at 68° it would be necessary to develop for 1½ to 2 minutes with intermittent agitation to be equivalent to 5 minutes at 70° with conventional processing. In order to attain full development within 1 minute, temperatures of 72° to 76° would be necessary which would not be harmful if polyester-base films are used. It was, therefore, decided to rate this procedure as "Underdevelopment" rather than "Per Manufacturer," since the latter classification would be equated with developing for 4½ minutes ±0.5 minute. As an example of what might be expected if developing were "complete", one dentist (included in this report), experimented and found that by changing the development time from 1 minute at 68° to 2½ minutes, he was able to reduce exposures by 30 percent.

Average roentgens per film

In order to establish a base with which to evaluate exposure levels, figure 1 was developed, showing average exposure per film at typical peak kilovolts (kVp) in offices developing Speed Group D film according to manufacturer's standards or longer for a given temperature.

This report does not discuss exposure to areas of the body or head other than that measurable directly under field conditions--the skin of the patient in air at the cone tip--and no effort is made to calculate an integrated dose. The purposes were: 1. to record levels of the exposure in air as found; 2. to indicate the degree to which these exposures can be reduced through the use of fast film and proper darkroom film processing; and, 3. to suggest exposure levels at various kVp's acceptable when fast film is properly processed.

Any decrease in exposure will reduce the absorbed dose to critical organs which, in the case

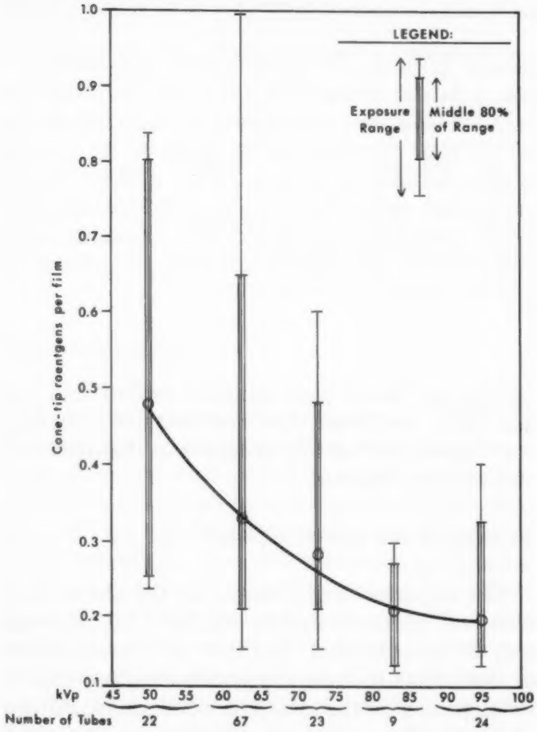

Figure 1. Cone-tip roentgens per film at various kVp levels in offices using fast film and developing at manufacturer's standards or better

of dental roentgenography, are the lens of the eye and the thyroid gland. Persons interested in absorbed doses are referred to Richards and Webber (*3*), who report exposures to those areas ranging from 0.8 percent to 2.6 percent of the total exposure. Focht et al. (*4*) report exposure to the eye to range from 10 mrem for a single lower bicuspid x-ray exposure to 1,000 mrem for an upper bicuspid. The gonadal exposure to the patient is extremely low in properly conducted dental x-ray procedures (*5–6*). Kline et al. (*7*) reports the male gonadal exposure (measured with thermoluminescent dosimeters) to be 0.39 mR per 10,000 mR of direct-beam exposure at the cone tip at 65 kVp, and 0.66 mR per 10,000 mR at 90 kVp. If the patient were draped with a leaded apron, or a lead-lined open cone were used, exposures would be even less.

The reduction in exposure per film with increasing kilovoltage is obvious, but this is not the complete picture. Richards and Webber (*3*) state that with 90 kVp the tissues lying shallower than the film depth receive smaller doses, while the tissues lying deeper receive greater doses than when a lower energy beam (65 kVp) is used; the exit dose is higher at increased kVp.

The excessively wide range of exposure levels shown in figure 1 suggests that while some dentists are diagnosing from films which are rather lightly exposed, a significant number are demanding films with densities which are unnecessarily high.

A final comparison, probably the most dramatic demonstration of the effectiveness of the program, is shown in figure 2. Instead of being limited to the 234 x-ray machines discussed so far, it represents 395 x-ray machines throughout the county. The additional 161 tubes were located during the continuing survey program, the results of which are not otherwise included in this report.

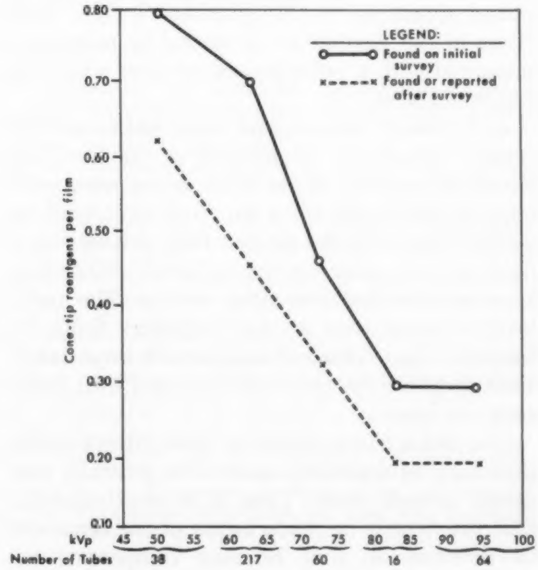

Figure 2. Mean cone-tip roentgens per film before and after survey (all film speeds, all developing techniques)

Electric and electronic timers

Timer accuracy is mentioned because the dentist, while aware of inaccuracies inherent in mechanical timers, is likely to assume that an electric or electronic timer is accurate. Unfortunately, this expected accuracy is not necessarily assured.

Table 6. Range of error in electric and electronic timers

Manufacturer	Number of timers	Timers accurate ± 10 percent	Timers overexposing		Timers underexposing	
			Number	Range of error (percent)	Number	Range of error (percent)
A	23	11	10	12½–100	2	17–33
B	30	12	18	12½– 67	—	
C	8[a]	8	—		—	
D	14	—	14	17 –400	—	
E	7	3	1	25	3	14–70
F	14	6	6	12 – 20	2	20–65
Total	96	40	49		7	

[a] This model is clearly identifiable as an impulse timer.

Table 6 shows findings on commonly encountered equipment based upon tests made with a spinning top timer on the majority of units equipped with an electric or electronic timer. Reproducibility was not checked on all units. Short exposure times were measured by actual count of the 60-cycle pulses appearing on the spinning-top film, while those in the vicinity of ¾ second or more were measured with a polar protractor over which the film was placed.

A review of the original data makes possible certain statements. Significant is the fact that almost 90 percent of the timer errors were overlong for when a film turns out too dark at what the dentist thinks is the proper time setting, he is likely to compensate in the darkroom rather than experiment with shorter timer settings. The higher levels of error were at short exposure times (¼ second or less). This is of considerable importance, since these are the timer settings used with short-cone machines.

One useful characteristic of these timers is that they may be depended upon to be generally consistent in their error. Thus, it is very important that the dentist be made aware of the error and its direction so that he may compensate accordingly.

Summary

In the course of making radiation safety surveys in 208 dental offices, using 234 x-ray tubes, in Oakland and Alameda and the county of Alameda, Calif., special emphasis was placed upon the use of fast film and proper processing of film. The total reduction in x-ray exposure resulting from these efforts was approximately 27 percent of the total original exposure. Although, the calculations are based upon dentists' replies and are not fully confirmed, the recommended changes were almost universally accepted as desirable and valid by the dentists.

Film speed and patient exposure

The importance of eliminating the use of slow films was demonstrated by the fact that although only 27 percent of all film used was intermediate or slow, films in those categories were responsible for 45 percent of the total patient exposure. Fifteen of the 65 offices involved made the recommended change, resulting in a 54 percent net reduction of their total exposure. Much effort remains to be directed in this area

Film processing and patient exposure

This portion of the program was clearly effective. As a result of the surveys, the number of offices developing film in an acceptable manner doubled with a reduction of 43 percent in exposure in those offices, and an overall exposure reduction of 22 percent. Darkroom procedures will be checked carefully on future visits, for it is likely that some offices will tend to revert to former careless habits in the darkroom.

Average roentgens per film

When fast film is developed properly, one may anticipate cone-tip exposures ranging from 0.62 roentgen per film at 45–55 kVp to 0.19 roentgen per film at 90–100 kVp. The range of exposure levels within the kVp groups is quite wide, suggesting that some dentists are demanding film density far above that required for good diagnosis.

Electric and electronic timers

Electric and electronic timers generally repeat accurately at any given exposure setting, but the actual exposure time may not agree with the dial setting. Of 96 units tested, only 40, mostly the newest models, were found to be accurate within ±10 percent. Most mechanical timers cannot repeat accurately any exposure times which would be required for good techniques with a short cone.

Recommendations

It may be assumed that in the future it will not be necessary to correct physical aspects of dental x-ray machines such as filtration and collimation. Therefore, it appears that the continuing program of resurveys will be most productive by emphasizing use of fast film and maximum developing techniques. Seventy-seven percent of the offices using slower films had not changed to fast film at the time of this report. Although the percentage of offices still approachable on film processing is less, a considerable amount of patient exposure couls still be reduced, and some backsliding in "improved" offices is anticipated. Even those offices developing according to manufacturer's standards should be encouraged to adopt the "maximum" technique, as evidenced by table 2.

In discussing film speeds with dentists, it is strongly recommended that the American National Standards Institute speed designation be routinely used in conjunction with any brand names which might be discussed. This would minimize the confusion between Speed Group D films and other films with fast-sounding names which are actually in the slower Group C.

Acknowledgments

The writers are indebted to the following members of the staff of the Alameda County Health Department: Robert L. Hanzel, health physicist, for his review and comments during the formative as well as later stages prior to preparation of final draft of this report; Karen Gardner, former chief statistician, for her review and suggestions for revision of the original statistical data for presentation; and W. W. Sampson, vector control specialist, for his guidance in the format of presentation. We are similarly indebted to Robert D. England, senior health physicist, Albert C. Starr, former assistant chief (Administration), and Mrs. Patricia Siegert, associate public health statistician of the Bureau of Radiological Health, California State Department of Public Health, for their review, evaluation, and assistance prior to preparation of the final draft.

REFERENCES

(*1*) COUNCIL ON DENTAL RESEARCH. Council adopts American Standard speed classifications for intraoral dental radiographic film: diagnostic grade. J Amer Dent Ass 65:280–283 (1962).

(*2*) WUEHRMAN, A. H. and L. R. MANSON-HING. Dental Radiology. C. V. Mosby Company, St. Louis (1965) p. 75.

(*3*) RICHARDS, A. and R. L. WEBBER. Dental x-ray exposures of sites within the head and neck. Oral Surg:754 (December 1964).

(*4*) FOCHT, E. F., G. R. MERRIAM, and J. A. EVANS. Dose to the eye from radiographic exposures. Radiology 76:459–463 (March 1961).

(*5*) ANON (no date). Appendix 21 to 1966 Congressional Hearings on Proposed Legislation Relating to Uniform Record Keeping and Workmen's Compensation Coverage for Radiation Workers. Table 1, footnote 12, p. 819.

(*6*) RICHARDS, A. G. Gonadal irradiation of dental patients. J Amer Dent Ass 65:1–11 (July 1962).

(*7*) KLINE. A. B., JR., H. F. STEWART, W. WELLOCK, and A. MAITLAND. Dosimetric evaluation of 30 dental facilities in Massachusetts: Measurement of workload related to exposure to environs. Oral Surg Med Pathology 29:44–58 (January 1970).

Survey Results of the Use of X Rays in the Healing Arts Specialties in North Dakota, 1964–1968

James A. Kraeger and *Gene A. Christianson*[1]

The x-ray facilities of all healing arts specialties (except dentistry) in North Dakota were surveyed by the State Department of Health to determine the degree of compliance of the x-ray facilities with the recommendations published in NBS Handbook 76. An average of 8,529 patients is radiographed per week in the healing arts specialties in North Dakota, for a total of 443,508 patients radiographed per year. Hospitals and multiple-specialty clinics account for 81 percent of the radiographs. An average of 881 patients receives a fluoroscopic examination each week for a total of 45,812 examinations per year. Of this fluoroscopic workload, 88 percent are conducted in hospitals and multiple-specialty clinics. Fifty-eight percent of the diagnostic x-ray machines were found to be deficient upon initial evaluation. The majority of deficiencies were inadequate collimation and/or inadequate filtration of the useful x-ray beam. Major deficiencies resulting in an unnecessary genetically significant dose were found to exist in facilities that expose 195,676 persons annually. Forty-nine percent of the individuals operating x-ray equipment in North Dakota are not registered with the American Registry of Radiologic Technologists. Of the non-registered technicians, 76 percent had less than a year of x-ray training and 74 percent indicated that aspects of x-ray protection were not included in their training.

During the past 40 years, with the growth of diagnostic applications of x ray, increasing attention has been directed toward the possible effects of lower levels of radiation on present and future generations as well as to the somatic effects. In recognition of these effects, various scientific bodies have made recommendations to limit the irradiation of the human body (*1*). Between 1931 and 1960, the recommended American exposure limit was reduced from 0.2 rem per day to 5 rem per year for occupationally exposed individuals and 0.5 rem per year for non-occupationally exposed individuals (*2*, *3*).

A conservative assumption is that the somatic and genetic effects resulting from radiation exposure have no threshold and that a direct linear relationship exists between dose and biological response. This concept is based on firm evidence as to the effects of heavy dosages and the lack of evidence that low dosages do not produce biological effects (*1*). Thus, the basic philosophy of the Radiological Health Program of the North Dakota State Department of Health emerges as "obtaining the maximum benefit from the use of radiation with least human radiation exposure". The activities of the program focus upon the reduction of human exposure to radiation by practical methods, thereby enhancing the beneficial applications of radiation.

In the spring of 1964, the Radiological Health Program initiated the voluntary physical survey of the x-ray facilities of all healing arts specialties. For purposes of this discussion, the healing arts specialties are defined as hospitals, multiple-specialty clinics, general practitioners (private offices), chiropractors, osteopaths, chiropodists, and radiologists. The use of x ray in the healing arts specialties has received the most program attention since they represent the most prevalent source of x-radiation exposure to the largest segment of this State's population. It is this area in which the greatest results can presently be achieved in regard to radiation protection.

The principal purpose of the survey was to determine, by comprehensive evaluation, the degree of compliance of x-ray facilities with the recommendations established by the National Council on Radiation Protection and Measurements (NCRP) as published in "Handbook 76" of the

[1] Mr. Kraeger was Radiological Health Specialist, Division of Environmental Engineering, Environmental Health and Engineering Services, North Dakota State Department of Health, Bismarck, N. Dak. and is presently, Staff Officer, Office of Regional Operations, Bureau of Radiological Health, Rockville, Md. Mr. Christianson is Director, Division of Environmental Engineering, Environmental Health and Engineering Services, North Dakota State Department of Health, Bismarck, N. Dak.

National Bureau of Standards (*3*). These evaluations have been updated in accordance with the new and modified recommendations issued through the NCRP Report No. 33 (*4*).

Additional objectives of the survey were to:

1. reduce the patient and operator exposure without decreasing the benefits derived from the use of x rays,
2. establish criteria for future resurveys of this type in North Dakota.

The comprehensive evaluation of x-ray facilities includes radiation measurements to determine the radiation exposure of the operator, patient, and people outside the immediate x-ray area; the acceptability of x-ray equipment based on current standards; the evaluation of other portions of the x-ray facility necessary to its operation (film development processes and monitoring record systems); and a discussion with the operating staff on the areas which need attention and those which could eliminate unnecessary radiation exposure. Because of economics and for uniformity for national data recall, the U. S. Public Health Service x-ray protection survey forms were utilized. To accelerate the recall of this information, the data from the survey forms were transferred to automatic data processing cards. The information of interest was obtained through the use of a card sorter.

The information collected in the evaluation of 364 x-ray machines used by the healing arts specialties in North Dakota is presented in the tables and discussions below. By the end of 1968, 97 percent of the x-ray machines registered with the State Department of Health had received the initial evaluation.

An average of 8,529 patients were radiographed per week in the healing arts specialties, for a total of 443,508 patients radiographed per year. Eighty-one percent of the patients were radiographed in hospitals and multiple-specialty clinics. A low estimate would be an "average" of two exposures per patient or a total of 887,016 radiographic exposures per year. This estimate does not include spot films associated with fluoroscopy. An average of 881 patients were fluoroscoped per week for a total of 45,812 patients fluoroscoped per year. Of these patients, 88 percent were fluoroscoped in hospitals and multiple-specialty clinics.

Radiographic units

Personnel, workload and equipment

Fifty-three percent of the healing art specialties never used a personnel monitoring system (table 1). The x-ray machines of the healing arts specialties were operated by 477 individuals of whom 45.5 percent were not monitored. In many instances, because the workload was minimal and the location of the operator was adequate, it was calculated that the operator in his normal functions would not receive an exposure exceeding one-fourth of the applicable maximum permissible dose (MPD) in any calendar quarter. Additionally, many of the operators were physicians who declined to monitor themselves. This was found to be especially true for the general practitioners and chiropractors. Whenever it appeared that the operator's exposure could exceed 25 percent of the applicable MPD, it was suggested that a monitoring system be instituted.

In one instance, the monitoring system of the facility was rated inadequate because the x-ray operator was not covered by the monitoring service, and in another instance the adequacy of the monitoring system was not determined because the records were unavailable at the time of the survey. Ten monitoring record systems were inadequate because complete up-to-date records of exposure for each occupationally exposed individual were not being maintained.

Personnel monitoring systems were employed in 47 percent of the x-ray facilities. In all instances, the monitoring device employed was the film badge. The monitoring records of 36 individuals in these facilities indicated they had received 300 mR for one or more quarters. The maximum quarterly dose reported was 2.7 rem.

Occupational exposures

As indicated in table 2, several improper procedures are believed to lead to these increased film badge exposures. Due to numerous instances of improper utilization of the film badges, it is difficult to determine whether these dose equivalent values indicated unnecessary exposures. The most frequently recuring improper procedures are:

1. The film badge used to estimate whole body exposure was worn on the outside of the lead

Table 1. Facility information from x-ray protection survey of healing art specialties in North Dakota

Facility information	Type of facility or type of practice							
	Hospitals	General practitioners in private offices	Multiple specialty clinics	Chiropractors	Radiologists	Orthopedists	Osteopaths	Chiropodists
Number of facilities	66	50	37	46	4	3	3	2
Personnel:								
Number of personnel occupationally exposed	297	110	141	53	9	4	4	3
Number of x-ray machine operators	231	74	105	53	4	4	3	3
Number of personnel monitored	198	19	104	2	6	4	0	0
Number over 300 mR/quarter	23	1	11	0	1	0	([a])	([a])
Workload: (Average number of patients per week)								
Radiographed	4,135	867	2,805	349	181	181	5	6
Fluoroscoped	469	35	297	4	75	0	1	0
Equipment:								
Number of x-ray machines	186	53	66	46	5	3	3	2
Number of x-ray tubes	244	65	91	47	8	3	3	2

[a] Undetermined—no personnel monitoring system employed.

Table 2. Range of documented dose-equivalent values for occupationally exposed individuals[a] and probable procedures leading to the increased exposures reported

Profession	Maximum mR/month	>300 mR/quarter	Dose equivalent value for year[a] (rem)	Probable procedures leading to increased exposure
Urologist	2,740	Monitoring system discontinued	Monitoring system discontinued	Remaining in close proximity to x-ray tube during activation without wearing protective apparel.
Cardiologist	510	Transferred		Same as above.
Radiologist	310			Undetermined
Radiologist	581	Averaged over 300 mR for 3 quarters	1.303	Undetermined
Radiologic technologist	1,285		6.101	Wearing film badge on outside of protective apparel.
Neurosurgeons (2)			1.0 2.3	Same as above.
Radiologic technologist	1,123		1.434	Wearing film badge on outside of protective apparel. Supporting patients during radiographic procedures.
Radiologic technologist	307		0.576	Failure to wear lead apron while using mobile x-ray units.
Radiologic technologist (3)	400		1.3 1.6 1.7	Same as above.
Radiologist	510		1.9	Undetermined
Radiologist	730		2.3	Undetermined
Technician	430			Manually operating bucky grid during tube activation.
Technician	649		0.649	Failure to remain within the shielded control station during radiography.
Radiologic technologist	768		1.5	Wearing film badge on outside of protective apparel. Supporting patients during radiography.
Radiologic technologist	768		0.768	Undetermined

[a] As reported on the occupational radiation exposure report form by the film badge service contractor.

apron, thus indicating the exposure only to the protective apparel. It was common practice for the fluoroscopist to wear only one badge. It is recognized there is no standardized procedure for the location of a monitoring device and in the interpretation of its reading. It was routinely recommended during the survey that the film badge be worn beneath the protective apron. If there was concern regarding exposure to the extremities, the use of an extremity badge was recommended. In addition, leaving the personnel monitoring badges and the control badge in the x-ray area contributed to an erroneous recorded dose equivalent value.

2. Occupationally exposed individuals supported patients during radiography without wearing appropriate protective apparel such as a protective apron.

3. Occupationally exposed individuals used mobile radiographic equipment without consideration of proper techniques in radiation protection such as distance and protective apparel.

4. Occupationally exposed individuals did not utilize the protective barrier that was provided for them.

One of the healing arts specialties that presents a cause for concern regarding increased exposures

is the urologist. The x-ray facilities of urologists at 17 hospitals and multiple-specialty clinics were evaluated where the urologist performed retrograde pyelograms, cystograms, and kidney, ureter, and bladder examinations. Because of the techniques associated with these examinations (the injection of radiopaque dye by the urologist), it was necessary for the urologist to remain close to the patient during x-ray tube activation. The reasons for concern follow:

1. Only 12 percent of the facilities included the urologist under the radiation monitoring system.

2. Only 12 percent of the urologists wore protective apparel during the examination.

3. There were 20 cystoscopy x-ray machines surveyed. Of these, 40 percent displayed inadequate collimation and 25 percent of the beam diameters were large enough to expose infants to total body radiation from the primary beam. The scattered radiation to the urologist was also increased due to the inadequate collimation.

Darkroom procedures

Darkroom procedures employed in the x-ray facilities ranged from no darkrooms to the use of automatic film processors (table 3). The hospital which does not possess a darkroom utilizes the darkroom of an adjoining medical clinic. The radiographic workload of this particular hospital is less than one radiograph per week as only one mobile x-ray unit is employed. As might be expected, automatic film processors were employed only in facilities with sufficient workload to justify the expense of these units.

It is interesting to note that 13 percent of the facilities did not employ a temperature or time-measuring device in the darkroom. This is an area which was stressed in the x-ray protection surveys. Film processing is as important as the techniques involved in positioning the patient for the radiograph. A poorly developed radiograph could necessitate re-examination, thus re-exposing the patient. Both a timer and a temperature indicator must be employed in the tank development of x-ray films. The time-temperature relationships of the development process are not of an arbitrary nature. They provide the criteria for obtaining the best quality radiograph.

Sight development is highest in those facilities (general practitioners in private offices and chiropractors) which also do not employ time and temperature control in tank development. Only 10 percent of the facilities employed sight development. Sight development of x-ray films is not considered good technique as it demands more attention and greater judgment on the part of the person developing the film than following the simple time-temperature recommendations of the developer manufacturer. In the course of facility evaluations, some of the inherent drawbacks involved in sight development were enumerated,

Table 3. Facility information from x-ray protection survey of healing art specialties in North Dakota

Facility information Darkroom procedures	Type of facility or type of practice							
	Hospitals	General practitioners in Private offices	Multiple specialty clinics	Chiropractors	Radiologists	Orthopedists	Osteopaths	Chiropodists
Number of facilities	66	50	37	46	4	3	3	2
Light-tightness of darkroom:								
No darkroom	1	0	0	2	0	0	0	0
Light-tight	40	33	32	29	4	3	3	2
Not light-tight	25	17	5	14	0	0	0	0
Undetermined	0	0	0	1	0	0	0	0
Automatic processing used:								
Yes	12	0	8	0	3	2	0	0
No	54	50	29	46	1	1	3	2
Thermometer present:								
Yes	46	37	23	33	1	1	2	1
No	3	9	2	13	0	0	1	1
Thermostatically controlled	17	4	12	0	3	2	0	0
Timer present:								
Yes	60	43	37	33	4	3	1	2
No	6	7	0	13	0	0	2	0
Sight development	4	5	0	11	0	0	1	0

Table 4. Radiographic information from x-ray protection survey of healing art specialties in North Dakota

Radiographic information	Type of facility or type of practice							
	Hospitals	General practitioners in private offices	Multiple specialty clinics	Chiropractors	Radiologists	Orthopedists	Osteopaths	Chiropodists
Number of x-ray machines with radiographic capability	172	51	56	46	5	3	3	2
Combination (radiographic–fluoroscopic capability):								
Yes	71	43	36	10	5	0	2	0
No	101	8	20	36	0	3	1	2
Type of x-ray machine:								
Fixed radiographic	99	47	53	46	5	3	2	1
Mobile	73	4	3	0	0	0	1	1
Total filtration at beginning of survey: (mm of Al. equiv.)								
<1.5	29	15	5	10	0	0	0	0
1.5–2.4	17	10	7	14	0	0	0	0
≧2.5	123	25	43	21	5	3	2	0
Undetermined	3	1	1	1	0	0	1	2
Total filtration at end of survey: (mm of Al. equiv.)								
<1.5	9	3	0	1	0	0	0	0
1.5–2.4	8	2	2	0	0	0	0	0
≧2.5	152	45	53	44	5	3	2	0
Undetermined	3	1	1	1	0	0	1	2
Collimation:								
Proper	20	6	7	18	0	0	1	1
Improper	54	40	14	22	0	1	1	1
Variable	91	5	34	5	5	2	0	0
Undetermined	7	0	1	1	0	0	1	0

including variations in eye sensitivity, low light intensities within the darkroom, and the opacity of the uncleared film.

Filtration and collimation

The importance of proper x-ray beam collimation and filtration in reducing the average significant genetic dose to the population from diagnostic x ray is well documented (*5*). Obtaining proper collimation of the x-ray beam reduces the exposure to the patient, reduces the scattered radiation to the operator and improves the contrast of the recorded image on the radiographic film. Filtration removes the less penetrating useless component of the diagnostic x-ray beam.

A total of 93 percent of the x-ray machines with radiographic capabilities were surveyed (table 4). Due to remodeling of x-ray facilities or dismantlement of the x-ray machine, 7 percent of the x-ray machines were not surveyed. This accounts for the difference between the total number of x-ray machines enumerated in table 1 and the number of x-ray machines in table 4. Evaluation of adequacy or inadequacy of filtration was based on the recommendation of NBS Handbook 76 (*3*).

Of the 338 x-ray machines surveyed, less than 2 percent had a maximum rated kVp below 70. The maximum rated kVp was undetermined on less than 4 percent of the x-ray machines. These were older machines on which "lettered" dial indicators were used in place of kVp direct-reading dial indicators. On the bases of the criteria used, 32 percent of the x-ray machines were being operated with inadequate filtration.

An average of 2,163 patients per week were found to be radiographed by equipment with inadequate filtration. In essence, 25 percent of the patients receiving diagnostic x-ray examinations were being exposed to unnecessary radiation. No attempt was made to determine what dose significance could be applied to this major equipment deficiency. As a corrective procedure of the x-ray evaluation, filters were provided for 77 percent of the x-ray machines to the benefit of 1,692 patients. These x-ray machines will be evaluated on revisits to see if the filtration has been installed.

It is not always possible to determine the amount of added or built-in filtration without disassembling portions of the tube head and/or collimator. It is the policy of the North Dakota State Department of Health not to dismantle any portion of the x-ray machine. If the added or built-in filtration was not visible, the x-ray service and sales representatives were contacted for this information.

Forty percent of the x-ray machines displayed a primary x-ray beam larger than the area of clinical interest for one or more examinations. The area of clinical interest is defined by the dimensions of the film used for the examination. Radiation exposure of body parts not seen by a film was deemed unnecessary. An average of 1,584 patients per week were radiographed by equipment exposing patients to the primary beam beyond the area of clinical interest. The equipment exposing 45 percent of the patients to inadequate filtration also subjected them to the additional exposure resulting from improper collimation. No attempt was made in this survey to determine what dose significance could be applied to these combined major deficiencies.

Machines with excessive beam sizes were reported in 49 and 78 percent of chiropractors and general practitioners in private offices, respectively; whereas, for hospitals and multiple-specialty clinics, the respective percentages were 33 and 26. There is a direct relationship between the use of variable collimators and proper collimation. The increased usage of variable collimation in the hospitals and multiple-specialty clinics resulted in a lower percentage of improper collimation. This is in good agreement with national trends as reported by the Bureau of Radiological Health, Public Health Service (*6*). Providing equipment with variable collimators is commendable; however, improper use or misalignment of the collimator can negate its value. In several instances, a variable collimator was on the equipment but was improperly used or not used at all. In 4 percent of the facilities, the improper cone was being used when a proper cone was available.

The range of improper collimation extended from three times the diagonal dimension of a 14 by 17-inch film to excess constriction of the beam diameter resulting in image loss (cone cutting) on the radiograph. Furthermore, protective devices (gonadal shields) were not employed during radiographic procedures conducted with 66 percent of the x-ray machines possessing improper collimation.

Operator and environ protection

Based upon scatter radiation measurements, the estimated workload, and the direction of the primary x-ray beam, operator protection, when provided, was found to be adequate throughout this survey. Although the maximum permissible exposure dose was not exceeded, in most instances, the radiation exposure of these individuals could be reduced by a simple change in procedure.

The radiation exposure dose rates observed in the environs surrounding the x-ray facilities were all well within 10 mR per week; in the majority of the smaller x-ray facilities, no additional shielding was provided other than structural materials. The workloads of these facilities did not indicate the need for additional shielding. In 2 percent of the facilities there was insufficient shielding to protect individuals in uncontrolled areas from the primary x-ray beam. In all cases, the primary beam was directed toward a wall-hung chest cassette. In 80 percent of these facilities, the proper use of a cone or collimator would have significantly reduced the area requiring primary shielding.

Fluoroscopic units

Seventy-seven percent of the x-ray machines with fluoroscopic capability surveyed were in hospitals and multiple-specialty clinics. Only 5 percent of the x-ray machines were not of the tilting-table type. Twenty image-intensifying devices were in use during the initial survey program. These devices were in use in 18 percent of the hospitals and 22 percent of the multiple-specialty clinics.

Fluoroscopic screens and target-to-panel distance

The interlocking of the fluoroscopic screen with the x-ray tube and the adequacy of the leaded viewing screens were not found to be a major x-ray protection problem during the initial surveys. Adequate attenuation of the primary beam by the screen was found to be satisfactory in 85.6 percent of the x-ray machines surveyed (table 5).

The relationship between the high percentage of machines (52 percent) in which the primary x-ray beam is not limited to the fluoroscopic screen and the low percentage of machines (7 percent) with improperly functioning shutters is explained by that fact that to be considered improperly functioning, the shutters must fail to operate or must operate erratically. Therefore the shutters could function properly but be improperly adjusted, thus allowing the spread of the primary x-ray beam beyond the fluoroscopic screen.

Table 5. Fluoroscopic information from x-ray protection surveys of healing art specialties in North Dakota

Fluoroscopic information	Type of facility or type of practice							
	Hospitals	General practitioners in private offices	Multiple specialty clinics	Chiropractors	Radiologists	Orthopedists	Osteopaths	Chiropodists
Number of x-ray machines with fluoroscopic capabilitiy	72	20	25	4	4	0	1	0
Fluoroscopic screen ganged to x-ray tube:								
Yes	70	20	25	4	4	0	1	0
No	0	0	0	0	0	0	0	0
Undetermined	2	0	0	0	0	0	0	0
Shutter functioning:								
Properly	63	12	22	3	4	0	1	0
Improperly	2	4	2	1	0	0	0	0
Undetermined	7	4	1	0	0	0	0	0
Useful beam limited to screen:								
Yes	33	5	5	2	3	0	1	0
No	33	11	19	2	1	0	0	0
Undetermined	6	4	1	0	0	0	0	0
Leaded screen:								
Satisfactory	60	16	24	4	3	0	1	0
Not satisfactory	0	0	0	0	0	0	0	0
Not applicable	5	0	0	0	1	0	0	0
Undetermined	7	4	1	0	0	0	0	0
Target-to-panel distance (inches):								
<12	0	0	0	0	0	0	0	0
12–14	3	7	2	0	0	0	0	0
15–17	25	10	12	1	2	0	1	0
18–20	37	2	11	3	2	0	0	0
≧21	2	0	0	0	0	0	0	0
Undetermined	5	1	0	0	0	0	0	0

The target-to-panel distance for all the machines surveyed met the recommendation (not less than 12 inches) in NBS Handbook 76. In fact, 86 percent of the machines had a target-to-panel distance of at least 15 inches. This distance complies with the revised design recommendation as described in NCRP Report No. 33 (*4*).

Filtration and roentgen output at the panel surface

Of the 126 fluoroscopic machines surveyed, 16 percent were being operated with inadequate filtration (table 6). An average of 21 examinations per week was being performed on the fluoroscopic machines with inadequate filtration, with no examinations being performed on six machines.

Table 6. Fluoroscopic information from x-ray protection survey of healing art specialties in North Dakota

Fluoroscopic information	Type of facility or type of practice							
	Hospitals	General practitioners in private offices	Multiple specialty clinics	Chiropractors	Radiologists	Orthopedists	Osteopaths	Chiropodists
Number of x-ray machines with fluoroscopic capability	72	20	25	4	4	0	1	0
Total filtration at beginning of survey (mm of Al. equiv.)								
<1.5	3	3	0	1	0	0	0	0
1.5–2.4	5	3	1	2	0	0	0	0
≧2.5	58	10	23	1	4	0	1	0
Undetermined	6	4	1	0	0	0	0	0
Total filtration at end of survey (mm of Al. equiv.)								
<1.5	2	1	0	1	0	0	0	0
1.5–2.4	4	0	0	2	0	0	0	0
≧2.5	60	15	24	1	4	0	0	0
Undetermined	6	4	1	0	0	0	1	0
Roentgen output at panel surface: (R/min)								
<1	4	0	2	0	0	0	0	0
1.0–4.9	36	7	16	1	3	0	1	0
5.0–9.9	24	5	6	1	1	0	0	0
10.0–14.9	1	1	0	1	0	0	0	0
15.0–19.9	1	1	0	0	0	0	0	0
≧20.0	0	0	0	1	0	0	0	0
Undetermined	6	6	1	0	0	0	0	0

During the survey, filters were provided for eight x-ray machines.

Less than 6 percent of the machines surveyed exceeded the 10 roentgens-per-minute panel surface exposure rate for routine fluoroscopy. An average of five examinations per week was performed on the x-ray machines exhibiting an exposure rate of greater than 10 R/min. On two of the x-ray machines no examinations were performed. Sixty-one percent of the machines exhibited an exposure rate measurement of less than 5.0 roentgens per minute. This would indicate that the performance standards described in NCRP Report No. 33-- that fluoroscopic machines produce exposure rates of less than 5 R/min at the table top-- can be implemented with modern equipment (*4*).

Accessory shielding

Lead gloves and lead aprons for use with fluoroscopy were found in over 94 percent of the facilities surveyed (table 7). On the other hand, the availability and use of a bucky grid slot cover and lead drapes were found in only 52 and 24 percent of the facilities. In part, the absence of the bucky grid slot cover and lead drapes reflects the age of the equipment. However, several physicians indicated that the bucky grid slot cover, if not fitted properly, interfered with the spot film radiograph. (The image of the bucky grid slot cover was recorded on the radiograph.) In addition, it was reported that the lead drapes interfered with patient manipulation and therefore added to the length of the fluoroscopic examination.

Timer information and light-tightness of fluoroscopic room

Of all the healing arts specialties surveyed, 91 percent used the deadman type of exposure switch on their fluoroscopic x-ray unit (table 8). In one facility, the deadman type exposure switch was altered, maintaining the circuit-closing contact without continuous pressure on the switch.

Of the total fluoroscopes evaluated, 58.5 percent were not equipped with manually reset cumulative timers. While the timer does not insure safe operation, it is of value to the physician as a means for gauging the passage of time. Since this timer can be an expensive addition to old equipment and can be demonstrated by the physician, another means of determining the duration of tube activation the manually reset cumulative timer does not have to be obtained for older equipment.

Of the facilities employing conventional fluoroscopic equipment, 59 percent lacked light-tight fluoroscopic rooms. Extraneous light can interfere with the fluoroscopic examination. Inasmuch as darkening the fluoroscopic room presents no real problem, this item could be easily corrected. Upon resurvey, this item will be re-evaluated.

Table 7. Fluoroscopic information from x-ray protection surveys of healing art specialties in North Dakota

Fluoroscopic information	Type of facility or type of practice							
	Hospitals	General practitioners in private offices	Multiple specialty clinics	Chiropractors	Radiologists	Orthopedists	Osteopaths	Chiropodists
Number of x-ray machines with fluoroscopic capabilitiy	72	20	25	4	4	0	1	0
Leaded gloves:								
Yes	67	19	24	2	4	0	1	0
No	3	1	1	2	0	0	0	0
Undetermined	2	0	0	0	0	0	0	0
Leaded apron:								
Yes	68	17	25	4	4	0	1	0
No	3	3	0	0	0	0	0	0
Undetermined	1	0	0	0	0	0	0	0
Bucky slot cover:								
Yes	42	5	15	0	3	0	0	0
No	25	14	10	3	1	0	0	0
Not applicable	3	1	0	1	0	0	1	0
Undetermined	2	0	0	0	0	0	0	0
Leaded drapes around screen:								
Yes	23	1	4	0	2	0	0	0
No	46	19	21	3	1	0	1	0
Not applicable	1	0	0	1	1	0	0	0
Undetermined	2	0	0	0	0	0	0	0

Table 8. Fluoroscopic information from x-ray protection surveys of healing art specialties in North Dakota

Fluoroscopic information	Type of facility or type of practice							
	Hospitals	General practitioners in private offices	Multiple specialty clinics	Chiropractors	Radiologists	Orthopedists	Osteopaths	Chiropodists
Number of x-ray machines with fluoroscopic capability	72	20	25	4	4	0	1	0
Deadman type of exposure switch:								
Yes	70	20	25	3	4	0	1	0
No	0	0	0	1	0	0	0	0
Undetermined	2	0	0	0	0	0	0	0
Manually reset cumulative timer:								
Yes	39	1	8	1	2	0	0	0
No	30	19	17	3	2	0	1	0
Undetermined	3	0	0	0	0	0	0	0
Cumulative timer terminates exposure:								
Yes	35	1	8	1	2	0	0	0
No	30	19	17	3	2	0	1	0
Undetermined	7	0	0	0	0	0	0	0
Light-tightness of fluoroscopic room:								
Light-tight	22	9	9	1	1	0	1	0
Not light-tight	41	10	10	2	0	0	0	0
Not applicable	7	0	6	0	3	0	0	0
Undetermined	2	1	0	1	0	0	0	0

X-ray technician manpower

Correction of x-ray equipment deficiencies does not provide assurance that radiation exposure to the operator and the general public is at its lowest practical level. As mentioned earlier, the improper use of variable collimators, the improper use of cones when proper cones were available, and the improper palcement of the personnel monitoring film badge, resulting in possible invalid dose equivalent values being recorded, negated their value. These are examples of a poor understanding of radiation protection on the part of the x-ray operator. In order to obtain the overall objective of prevention or reduction of unnecessary radiation exposure from the diagnostic medical uses of x ray, the individuals who operate the x-ray equipment must be well versed in radiation protection as well as in the techniques necessary for a good radiograph.

The North Dakota State Department of Health instituted a survey in 1968 to obtain information on the extent of training and experience of the operators of x-ray equipment in the healing arts. A total of 387 X-ray Technician Manpower Survey forms were mailed. Of these, 248 forms were returned with 218 forms completed for a 63.9 percent return. Two major groups are categorized in this discussion: registered radiological technologists and non-registered x-ray technicians.

To define the term "registered technologist", it was specified that the individual must have attended a planned program of training in a school of radiologic technology and/or be registered with the American Registry of Radiologic Technologists.

From the 218 replies, 84 (38 percent) were registered radiologic technologists and 107 (49 percent) were non-registered technicians. Students enrolled in approved schools of x-ray technology accounted for the remainder of those replying.

The American Registry of Radiologic Technologists indicated that there were 170 certified registered radiologic technologists in the State of North Dakota (*7*). Therefore, approximately 50 percent of the radiologic technologists are either not practicing for one reason or another or did not return the manpower survey form.

As of July 29, 1968, 65 radiologic technologists were listed as active members of the North Dakota Society of Radiologic Technologists. Since this society has an active education program, there is a need to increase membership in the State society to reach all registered technologists and keep them abreast of recent developments in radiographic techniques and radiation protection.

Personal characteristics

A look at the personal characteristics of the total group (table 9) reveals that 64 percent of the group were female, 59 percent of whom were married. Of the men, 92.5 percent were married.

Table 9. Sex, age, and marital status of radiologic technologists and non-registered technicians by facility where employed

	Registered technologists					Non-registered technicians			
	Hospitals	Clinics	Hospitals and clinics	Private offices	Other	Hospitals	Clinics	Hospitals and clinics	Private offices
Sex:									
Male	24	7	6	0	1	18	8	3	0
Female	19	14	8	5	0	38	32	2	5
Not reported	0	0	0	0	0	1	0	0	0
Total	43	21	14	5	1	57	40	5	5
Age:									
≤24 Male	8	0	1	0	1	7	1	0	0
≤24 Female	4	8	5	3	0	10	5	2	0
25–34 Male	7	4	3	0	0	5	4	0	0
25–34 Female	6	1	3	2	0	12	9	0	1
35–44 Male	6	1	1	0	0	5	2	2	0
35–44 Female	4	2	0	0	0	10	11	0	0
45–54 Male	2	1	0	0	0	1	1	1	0
45–54 Female	2	1	0	0	0	2	7	0	2
≥55 Male	1	1	1	0	0	0	0	0	0
≥55 Female	3	2	0	0	0	3	0	0	1
Not reported	0	0	0	0	0	2	0	0	1
Marital status:									
Single: Male	2	0	0	0	0	1	0	1	0
Single: Female	9	7	3	1	0	15	8	0	2
Married: Male	22	7	6	0	1	16	8	2	0
Married: Female	8	7	5	4	0	20	24	2	3
Widowed or divorced: Male	0	0	0	0	0	1	0	0	0
Widowed or divorced: Female	2	0	0	0	0	3	0	0	0
Not reported	0	0	0	0	0	1	0	0	0

The data indicate that 58 percent of the females and 61 percent of the males were less than 35 years of age. Comparing the registered and non-registered groups 67 percent of the registered group are less than 35 years of age, whereas 45.5 percent of the non-registered group are in that age category.

Type of x-ray training of the non-registered technician

In comparing the training of the registered technologist and non-registered technicians (table 10), the registered technologist either completed a formal training program (minimum of 24 months in a planned program of training in a school of radiologic technology) and/or completed on-the-job training which qualified him for registration with The American Registry of Radiologic Technologists. The type of training received included diagnostic x ray only (23 percent); diagnostic and therapeutic x ray (51 percent); diagnostic, therapeutic and radioisotope training (20 percent), while 6 percent did not indicate the specific type of training. Of the nonregistered technicians, 76 percent had less than one year of x-ray training. In addition to lack of extensive training, 74 percent indicated that radiological health and/or x-ray protection were not included in their training. Although the largest percentage of the nonregistered technicians had no formal training, 51 percent indicated they received their training from a radiologist, a registered technologist, or a combination of both.

Employment distribution of registered and non-registered technicians

Hospitals and multiple specialty clinics employ 93 percent of the registered technologists (table 11) and 95 percent of the non-registered technicians (table 12). Based on data from the x-ray protection and x-ray technician manpower surveys, x-ray technicians were not employed by chiropractors, chiropodists and osteopaths.

Even with the small number of x-ray resurveys conducted throughout the State, a large turnover of x-ray technicians had been observed. In order to gain an idea of the overall rate of turnover, the technicians were questioned on the duration of present employment and the number of years employed as an x-ray technician. As to the length of time employed at their present location, both the registered technologists and non-registered technicians reported approximately 71 percent had been employed for less than 5 years. There is little difference in the reported length of employment

Table 10. Non-registered technicians—type of x-ray training

	Duration of training period					Title of instructor							X-ray protection training received		
	<6 months	6 months to 1 year	>1 year	Degree	N.D.[a]	Rad[b]	RT[c]	Rad & RT	Phy[d]	Phy & RT	Other	N.D.[a]	Yes	No	N.D.[a]
Hospitals	24	18	8	2	5	4	19	9	12	4	4	5	40	9	8
Clinics	13	20	7	0	0	5	7	6	16	5	1	0	33	5	2
Hospitals and clinics	2	2	1	0	0	1	2	1	0	0	0	1	3	2	0
Private offices	0	2	3	0	0	0	0	1	4	0	0	0	3	1	1
Total	39	42	19	2	5	10	28	17	32	9	5	6	79	17	11

[a] No data.
[b] Radiologist.
[c] Radiologic technologist.
[d] Physician.

Table 11. Employment distribution of radiologic technologists

	Employment status		Length of time at present location					Length of time in x-ray field				
	Full-time	Part-time	<1 year	1–5 years	6–10 years	>10 years	N.D.[a]	<1 year	1–5 years	6–10 years	>10 years	N.D.[a]
Hospitals	37	6	13	18	3	9	0	5	14	8	16	0
Clinics	21	0	6	6	2	7	0	1	8	2	10	0
Hospitals and clinics	14	0	4	8	0	2	0	3	7	2	2	0
Private offices	4	1	3	1	1	0	0	2	1	1	0	1
Other	1	0	1	0	0	0	0	0	1	0	0	0
Total	77	7	27	33	6	18	0	11	31	13	28	1

[a] No data.

Table 12. Employment distribution of non-registered technicians

	Employment status			Length of time at present location					Length of time in x-ray field				
	Full-time	Part-time	N.D.[a]	<1	1–5	6–10	>10	N.D.[a]	<1	1–5	6–10	>10	N.D.[a]
Hospitals	38	19	0	20	25	6	6	0	9	19	14	9	6
Clinics	34	5	1	8	20	7	4	1	6	14	8	9	3
Hospitals and clinics	5	0	0	2	0	1	2	0	2	0	1	2	0
Private offices	4	0	1	0	1	0	3	1	0	0	1	3	1
Total	81	24	2	30	46	14	15	2	17	33	24	23	10

[a] No data.

in the field of x ray for the registered technologist and non-registered technician. The registered technologists reported 50 percent had been in x-ray work less than 5 years, whereas the non-registered technicians reported 47 percent had worked less than 5 years. There is a 5 percent difference between the number of registered technologists and the number of non-registered technicians who had worked longer than 5 years. Conversely, 13 percent of the non-registered technicians were working on a part-time basis as compared to 8 percent of the registered technologists.

There is a difference between the workload of the facility which employs a registered technologist as opposed to one which employs a nonregistered technician. Facilities employing the registered technologist averaged 61 radiographic patients and 12 fluoroscopic patients per week with an average of three radiographic exposures per patient. Facilities employing the nonregistered technician averaged 21 radiographic patients and three fluoroscopic patients per week with an average of two radiographic exposures per patient. This difference was expected since the registered technologist is employed in hospitals and multiple-specialty clinics where more sophisticated x-ray procedures are conducted, resulting in more radiographs per patient.

In review, 49 percent of the individuals operating x-ray equipment in North Dakota are not registered with the American Registry of Radiologic Technologists. It appears that the non-registered technician remains in the field of x ray for approximately the same length of time as the

registered technologist, although 76 percent of the non-registered technicians have had less than 1 year of x-ray training.

The X-ray Technician Manpower Survey contained a question which asked if the x-ray technicians would be interested in attending a short course or seminar on radiological health and/or x-ray protection. Over 85 percent responded favorably to the proposed course; however, scheduling problems have arisen for the technician in the small facility due to the difficulty of leaving the facility for even 1 day. It is encouraging, however, that the technicians have expressed this interest in increasing their skills and understanding of radiation protection in x-ray facilities.

Summary

Approximately 8,500 patients are radiographed per week in the healing arts specialties, for a total of 443,500 patients per year. Eighty-one percent of the radiographs are performed in hospitals and multiple-specialty clinics. An average of 881 patients receive a fluoroscopic examination each week for a total of 45,812 examinations per year. Of this fluoroscopic workload, 88 percent are conducted in hospitals and multiple-specialty clinics.

Fifty-eight percent of the diagnostic x-ray machines were found to be deficient upon initial evaluation. The majority of the deficiencies were with respect to inadequate collimation and/or inadequate filtration of the useful x-ray beam. Major deficiencies resulting in an unnecessary addition to the genetically significant dose were found to exist in facilities that expose 195,676 persons annually.

Currently, complete resurveys are being conducted to determine the degree of compliance with the recommendations of the initial evaluation and with the Radiological Health Regulations (*8*).

Correction of x-ray equipment deficiencies does not provide assurance that radiation exposure to the operator and the general public is at its lowest practical level. In numerous instances the technicians have not made use of radiation protection devices and equipment available within the facility. As indicated from the X-ray Technician Manpower Survey, 40 percent of the individuals operating x-ray equipment in North Dakota are not registered with The American Registry of Radiologic Technologists. Of the non-registered technicians, 76 percent had less than a year of x-ray training and 74 percent indicated aspects of x-ray protection were not included in their training. It is firmly believed that to obtain the maximum benefit from the use of diagnostic x ray with least human radiation exposure, education must be the key.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, (May 13, 1960).
(*2*) BLATZ, HANSON. Introduction to Radiological Health. McGraw-Hill Book Company (1964).
(*3*) NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENTS. Medical X-ray Protection Up to Three Million Volts, National Bureau of Standards Handbook 76. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (February 9, 1961).
(*4*) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Medical X-ray and Gamma-Ray Protection for Energies Up to 10 MeV, Equipment Design and Use, NCRP Report No. 33. NCRP Publications, Washington, D.C. 20008 (February 1968).
(*5*) PUBLIC HEALTH SERVICE. Report of the Medical X-ray Advisory Committee on Public Health Considerations in Medical Diagnostic Radiology (X-Rays), October 1967. Bureau of Disease Prevention and Environmental Control, National Center for Radiological Health, Rockville, Md.
(*6*) FESS, R. and L. C. SEABRON. Preliminary Results of 5263 X-ray Protection Surveys of Facilities with Medical X-ray Equipment, MORP 68-6. PHS, Bureau of Radiological Health, (revised September 1968).
(*7*) AMERICAN SOCIETY OF RADIOLOGIC TECHNOLOGISTS. The American Registry of Radiologic Technologists, Spetember 1967.
(*8*) NORTH DAKOTA STATE DEPARTMENT OF HEALTH. North Dakota State Department of Health, Radiological Health Regulations, Regulation 83, March 1, 1968.

Strontium and Plutonium Isotopes in Ground Level Air October 1963-March 1969

B. Shleien, J. A. Cochran, and *P. J. Magno*[1]

Data are presented on monthly concentrations of strontium-90, strontium-89, plutonium-239, and plutonium-238 in ground level airborne particulates collected at Winchester, Mass. from October 1963 (for radioisotopes of strontium) and May 1965 (for radioisotopes of plutonium) to March 1969. The ratio of strontium-89 to strontium-90 in these samples indicates an influx of strontium-90 following all but the sixth atmospheric detonation on the Chinese mainland. It is estimated that in 1968 approximately 60 percent of the strontium-90 present in ground level air was of post-1963 origin. The ratio of plutonium-239 to strontium-90 prior to February 1968 was 0.017 ± 0.009. There was a gradual increase in this ratio later in 1968 which is attributed to debris following the sixth, seventh, and eighth tests on the Chinese mainland. Levels of plutonium-238 in SNAP-9A debris in ground level air are somewhat lower than had been predicted.

The radionuclides, strontium-90, strontium-89, plutonium-239[2], and plutonium-238, are present in the atmosphere as the result of nuclear weapons tests. In the case of plutonium-238 (in addition to the above source) an injection of this radioisotopes into the atmosphere took place in April 1964 when 17 kilocuries of plutonium-238, contained in a SNAP-9A power source, burned up south of the equator off the coast of Africa (*1*). Information on airborne strontium and plutonium isotopes is of interest in evaluating the potential health hazards of these materials and in investigating the transport processes involved. Analysis of ground level airborne particulate samples for the radioisotopes of strontium has been performed at the Northeastern Radiological Health Laboratory (NERHL) since October 1963. For the plutonium isotopes, radiochemical and alpha spectroscopic analysis has been done since May 1965. Results of these analyses to April 1966 (for strontium-90) and to February 1967 (for the plutonium isotopes) have been previously reported (*2, 3*). Extensive measurements of these radionuclides in air particulates and precipitation have been performed by the Health and Safety Laboratory (HASL) of the Atomic Energy Commission (AEC) for several years (*4, 5*). In addition, the Joint Nuclear Research Center, ISPRA Establishment, Italy, has published data on SNAP-9A plutonium-238 (*6*).

Results on ground level airborne concentrations of the above radionuclides from the inception of the sampling and analysis program at NERHL to March 1969 are presented. A recent assessment of doses from these radionuclides based on their concentrations, indicates that only an infinitesimal portion of the total strontium-90 dose to bone is due to inhalation of airborne material. On the other hand, the dose from plutonium-239 to the tracheobronchial lymph nodes was reported to be 160 millirem in 50 years, second in magnitude only to the dose from strontium-90 to the bone. The dose from plutonium-238 to this lymphatic tissue was about one-quarter of that from plutonium-239 (*7*). Attention will be given to the origin of these radionuclides and to the contribution of various atmospheric nuclear tests and the burnup of the SNAP-9A satellite to the total quantity of the radionuclides present

---

[1] Dr. Shleien is chief of Environmental Radiation Activities at the Northeastern Radiological Health Laboratory, Bureau of Radiological Health, Winchester, Mass.; Mr. Cochran and Mr. Magno are in charge of the Dosimetry and Environmental Methods Section, respectively, at this laboratory.

[2] The energies of the alpha particles from plutonium-239 and plutonium-240 are not sufficiently different to be separated by alpha-particle spectroscopy. Therefore, when plutonium-239 is referred to in this report, it is meant to represent the sum of the activities of plutonium-239 and plutonium-240.

in ground level air. A summary of reported atmospheric detonations or vents which occurred during the period of this study is given in table 1 (*8*).

Table 1. Reported atmospheric detonations (*8*)

Date	Source	Comments
October 16, 1964	Chinese mainland (1st)	Low[a]
May 14, 1965	Chinese mainland (2nd)	Low
May 9, 1966	Chinese mainland (3rd)	Intermediate 200 kilotons (kt)
July 2, 1966	French	25–30 kt
July 19, 1966	French	70–80 kt
September 11, 1966	French	120 kt
September 24, 1966	French	150 kt
October 4, 1966	French	Intermediate 200–300 kt
October 27, 1966	Chinese mainland (4th)	Low-intermediate 20–200 kt
December 28, 1966	Chinese mainland (5th)	Few hundred kt
June 5, 1967	French	Low
June 17, 1967	Chinese mainland (6th)	2 megaton (Mt)
June 27, 1967	French	Low
July 2, 1967	French	Low
December 24, 1967	Chinese mainland (7th)	Megaton range
July 7, 1968	French	Low
July 15, 1968	French	Low
August 3, 1968	French	Low
August 24, 1968	French	2 Mt
September 9, 1968	French	2 Mt
December 28, 1968	Chinese mainland (8th)	2 Mt

[a] Less than 20 kilotons.

Sampling and analysis procedures

Monthly composite particulate samples, representing 12,000 m^3 of air, are collected on 8- by 10-inch membrane filters (pore size 0.8 micron) at a height of 1 meter above the ground. The samples are wet ashed with a mixture of nitric and perchloric acids. The sample is split into two parts for radiochemical analysis.

One-half of the sample is analyzed for strontium–90 and strontium–89. Strontium carrier is added, and the strontium is precipitated from the samples first as the carbonate, then as the nitrate. Further purification is made by barium chromate precipitation and hydroxide scavenging. After an ingrowth period, yttrium carrier is added and the yttrium is extracted into TTA (2-thenolytrifluoroacetate) at pH = 5.0. The yttrium is stripped from the TTA with dilute nitric acid, precipitated as the oxalate and counted for beta particles of yttrium–90. The strontium is precipitated as the carbonate and counted for beta particles of total radiostrontium. The strontium–89 activity is calculated from the total radiostrontium measurement after correction for strontium–90 content.

Analysis of the other half of the sample for the plutonium isotopes is begun by adding plutonium–236 tracer. The plutonium is reduced to the +3 state and coprecipitated with lanthanum fluoride. The lanthanum fluoride is converted to lanthanum hydroxide and dissolved in 7.2 $\underline{M}$ nitric acid. The plutonium is oxidized to the +4 state. The solution is passed over an anion exchange resin in the nitrate form. The resin is washed with additional nitric acid and then with 9 $\underline{M}$ hydrochloric acid. The plutonium is then eluted from the resin with a mixture of 0.36 $\underline{M}$ hydrochloric acid and 0.01 $\underline{M}$ hydrofluoric acid, electroplated onto a stainless-steel planchet from a sulfuric acid-ammonium sulfate electrolyte, and counted with a silicon surface barrier detector linked to a multichannel analyzer. With the sample electroplated onto a 3.1 cm^2 area, the counting efficiency is $\sim$31 percent and resolution 75 keV.

The minimum detectable quantities are 0.10 fCi/m^3, 0.40 fCi/m^3, and 0.003 fCi/m^3 for strontium–90, strontium–89, and the plutonium isotopes, respectively. The maximum 2σ counting error for strontium–90 is approximately 10 percent of the reported value. The corresponding values for strontium–89 are about twice as high. The maximum 2σ counting errors are 50 percent and 67 percent of the reported values for plutonium–239 and plutonium–238, respectively, but are appreciably lower as the values increase above the minimum detectable levels.

Results and discussion

The results of strontium–90 analyses of ground level airborne particulates from monthly composite samples are presented in figure 1. Difficulties in sampling and analysis caused the loss of two samples (October 1963 and August 1967), and during a change over in personnel responsible for collection and analysis of the data, several months of ambiguous data (September, October, November, and December 1967) occurred. Figure 1 illustrates the expected spring maximum which occurs each year and which appears to be extremely reproducible in terms of time of appearance. A line (solid) indicating the expected spring maximum highs, based on the strontium–90 concentrations in the spring of 1964 and a stratospheric residence half-time of 10 months (*9*), is shown. The expected strontium–90 curve (dashed), having the shape of the 1964 curve, because no fresh

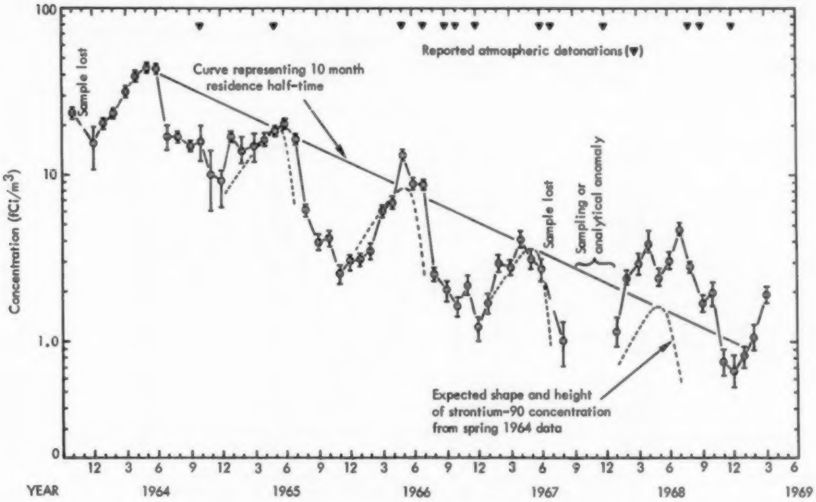

Figure 1. Strontium-90 in ground level air

intrusion of material occurred until the end of that year, is also shown. The difference between the expected and actual curves indicates strontium-90 of post-1963 origin was present.

A double peak in strontium-90 levels appears in 1968. Although not apparent from this study, other investigators have noted the presence of fresh fission products during August 1968 and attribute the rise in radioactivity to the rapid movement of debris from the French tests in July 1968 (*10*). Strontium-90 levels in the latter part of 1968 would be elevated if such an intrusion occurred. Another possibility is an influx of strontium-90 of stratospheric origin, although this is not apparent from the strontium-89 to strontium-90 ratios discussed later.

Strontium-89 concentrations are shown in table 2. Strontium-89 values are indicated only in months where the levels of this radionuclide were above the minimum detectable level. All the appearances of strontium-89 followed atmospheric tests on the Chinese mainland. This fact, together with information that, except in the case noted above, French tests were not measurable above 10°N latitude (*11*) and that the reported yields of releases at the Nevada Test Site (NTS) were low and of a limited nature (*8*), appears to make the detonations on the Chinese mainland the principal source of increases above the expected strontium-90 levels.

The contribution of strontium-90 from a particular test may be estimated from the strontium-89 to strontium-90 ratio. These estimates are also presented in table 2. The theoretical ratios are based on production yields for uranium-235 fission (*12*) and are corrected for decay time between the nuclear test and the time of collection. In most cases, the contribution of strontium-90 in ground level air from a recent nuclear test based on the strontium-89 ratios, appears to be of tropospheric origin. However, the strontium-89 to strontium-90 ratio following the fifth test on the Chinese mainland appears to be influenced by the presence of strontium-89 of stratospheric origin beginning in March of 1967.

Early low yield tests on the Chinese mainland contributed only small amounts to ground level strontium-90 concentrations. The fifth test on the Chinese mainland (December 28, 1966) appears to have contributed a substantial quantity of strontium-90. There was no evidence of a fresh strontium-90 intrusion following the sixth test on the Chinese mainland (June 17, 1967), although complete data are not available. For the 2 months

Table 2. Strontium-89 concentrations and contribution of fresh strontium-90 from atmospheric tests

Test and date	Sample collected (month and year)	Strontium-89 concentration (fCi/m³)	Time elapsed since test (days)	Ratio of strontium-89 to strontium-90		Strontium-90 from test (percent)
				Theoretical (*12*)	Measured	
Chinese mainland (1st) (Oct. 16, 1964)	Nov. 1964	10 ± 3[a]	30	111	1.6	1.5
	Dec.	(b)	60	74	(b)	---
	Jan. 1965	16 ± 3	91	49	.8	1.6
Chinese mainland (2nd) (May 14, 1965)	June 1965	57.9 ± 2.7	30	111	2.9	2.6
	July	28.2 ± 2.6	60	74	1.7	2.3
	August	2.4 ± 1.1	90	39	.3	.8
	Sept.	1.5 ± 1.2	120	33	.4	1.2
Chinese mainland (3rd) (May 9, 1966)	June 1966	13.1 ± 2.8	37	100	1.8	1.8
	July	10.4 ± 1.7	67	67	2.2	3.3
	August	4.3 ± .8	108	38	1.7	4.5
	Sept.	1.8 ± .7	139	25	.9	3.6
Chinese mainland (4th) (Oct. 27, 1966)	Nov. 1966	18.7 ± 1.7	19	129	8.5	6.6
	Dec.	6.5 ± .8	49	86	5.3	6.2
Chinese mainland (5th) (Dec. 28, 1966)	Jan. 1967	11.9 ± 1.2	19	129	7.0	5.4
	Feb.	15.5 ± 1.1	49	86	5.3	6.2
	March	27.4 ± 1.6	81	55	9.9	18
	April	34.7 ± 1.6	112	36	8.5	23
	May	14.0 ± 1.8	142	24	4.5	19
	June	5.3 ± .9	173	16	2.0	13
Chinese mainland (6th) (June 17, 1967)	No evidence of strontium-89 in August or September 1967. July sample lost and in September through December sampling or analytical ambiguities occurred.					
Chinese mainland (7th) (Dec. 24, 1967)	Jan. 1968	6.5 ± .6	22	124	5.8	4.7
	Feb.	18.3 ± 1.1	53	81	7.2	11
	March	14.8 ± 1.1	81	55	5.1	9.3
	April	13.1 ± 1.1	111	36	3.4	9.5
	May	3.1 ± .7	141	24	1.3	5.5
	June	2.9 ± .7	172	16	.9	5.6
Chinese mainland (8th) (Dec. 28, 1968)	Feb. 1969	2.3 ± .5	48	87	2.2	2.5

[a] 2σ counting error.
[b] Not determined.

following the test for which results were available, there was no indication of elevated strontium-89 levels. Data from the Health and Safety Laboratory (HASL) also indicate the absence of strontium-89 from this test[3] (*11*).

From the differences in projected and actual levels of strontium-90, an estimate of the strontium-90 from atmospheric testing after 1963 can be made. Table 3 presents the mean predicted (based on a 10-month residence half-time and the mean 1964 results) and measured strontium-90 concentrations in ground level air. Because of the magnitude of errors in analyses, it is believed that only the values for 1968 are truly significant, although a gradual increasing trend in newly injected strontium-90 since 1965 is indicated. In 1968, 62 percent of the total ground level strontium-90 was due to post-1963 tests. HASL estimates that 71 percent of the total reservoir of strontium-90 in 1968 could be attributed to post-1963 debris (*14*).

[3] It has been suggested that this device exploded at a comparatively low altitude (14 km), but that the bulk of the debris was carried to a high altitude by the rising fire-ball (*13*).

Table 3. Estimated contribution of post-1963 tests to strontium-90

Year	Mean strontium-90 concentration (fCi/m³)		Estimated contribution post-1963 tests (percent)
	Predicted	Measured	
1964	[a]24.1	24.1	—
1965	10.5	11.3	7
1966	4.6	4.6	—
1967	2.0	[b]2.3	15
1968	.9	2.4	62

[a] Predicted value based on measured results for 1964.
[b] No data for July, October, November, and December 1967.

Concentrations of plutonium-239 in ground level air particulates are presented in figure 2. The pattern of minimum and maximum is similar to that for strontium-90. The same limitations (sample loss and ambiguity) hold as for the strontium-90 data. The average ratio of plutonium-239 to strontium-90 for the period, May 1965 through February 1968, was 0.017 with a 2σ range of ± 0.009. There is a gradual rise in this ratio fol-

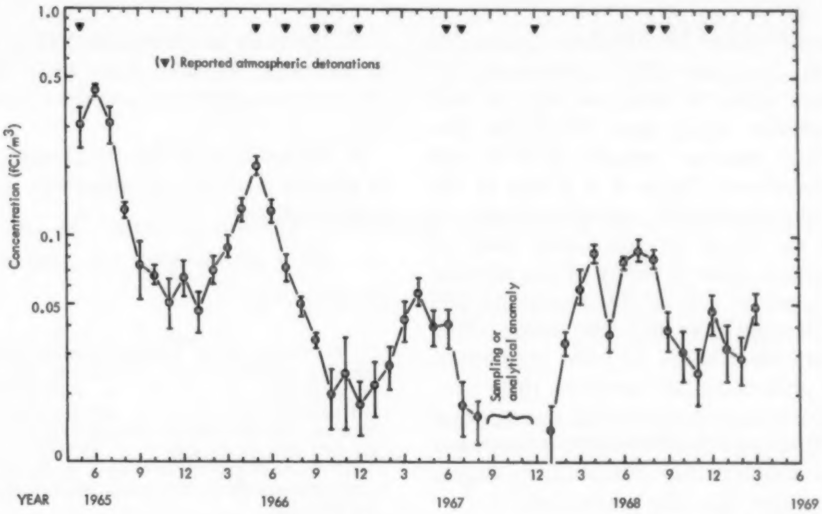

Figure 2. Plutonium-239 in ground level air

lowing this period, the average value being 0.028 from March 1968 to March 1969. This increase in the plutonium-239 to strontium-90 ratio is attributed to debris from the sixth, seventh, and eighth tests on the Chinese mainland, which were reported to be high yield events.

The ratio of plutonium-238 to plutonium-239 remained relatively constant at 0.04 ± 0.02 from May 1965 to July 1966. A change in the ratio was fairly evident at NERHL in mid-1966 (*3*). This change in ratio indicated a new source of plutonium-238 other than that which was pre-

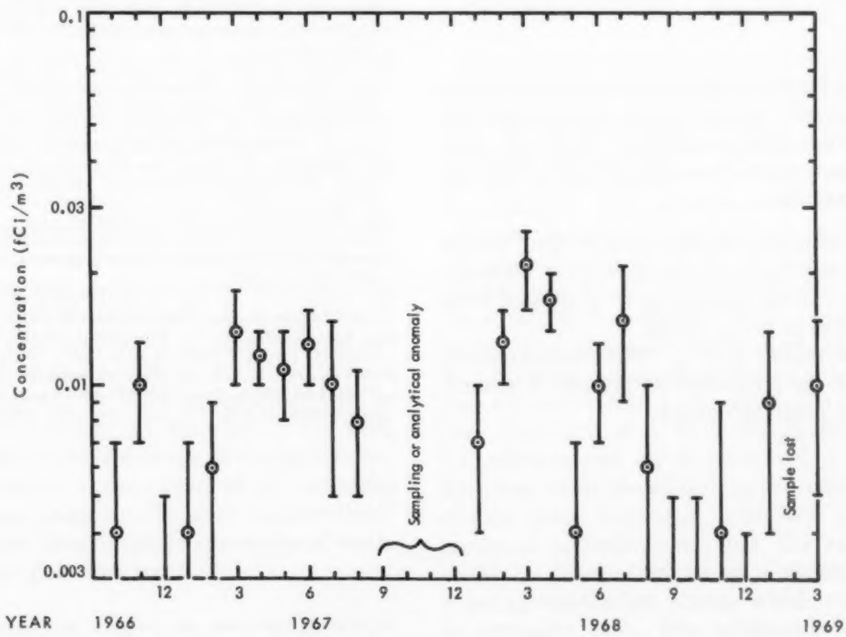

Figure 3. Estimated SNAP-9A plutonium-238 in ground level air

viously present. Other investigators announced this change in plutonium–238 to plutonium–239 ratio somewhat earlier in June and July of 1966 (*6*), the conclusion being that SNAP–9A plutonium–238 had reached ground level in the Northern Hemisphere. Figure 3 is a plot of the SNAP–9A plutonium–238 concentrations in ground level air based on the above ratio of plutonium isotopes prior to influx of the satellite debris. The levels of SNAP–9A plutonium–238 are slightly elevated over the 1967 levels. This elevation is expected, based on prior predictions of increasing plutonium–238 levels in 1968 (*15*). A comparison of the predicted results, the reported results at ISPRA, and NERHL results is presented in table 4. The NERHL results (3-month averages) are somewhat lower than the predictions.

Table 4. SNAP-9A plutonium in ground level air

Date	Concentration (fCi/m³)		
	Predicted	ISPRA	NERHL
January 1966	0.011	0.001	—
July 1966	.013	.003	—
January 1967	.015	.005	0.004
July 1967	.016	.015	.011
January 1968	.017	.012	.014
July 1968	.018	—	.010

Summary

Data have been presented on the concentrations of strontium–89, strontium–90, plutonium–239, and plutonium–238 in ground level air particulates. From these data, the following observations may be made:

1. the atmospheric nuclear tests on the Chinese mainland appear to have contributed the majority of the influx of fresh strontium–90 in ground level air particulates in recent years,

2. it is estimated that in 1968 approximately 60 percent of the strontium–90 present in ground level air is of post-1963 origin,

3. the ratio of plutonium–239 to strontium–90 is somewhat elevated since early 1968 following recent atmospheric tests on the Chinese mainland, and

4. the levels of SNAP–9A plutonium–238 debris in ground level air are somewhat lower than had been predicted.

REFERENCES

(*1*) HARLEY, J. H. Possible plutonium–238 distribution from a satellite failure. HASL–149:138 (October 1964).
(*2*) MAGNO, P. J., P. E. KAUFFMAN, and B. SHLEIEN. Plutonium in environmental and biological medica. Health Physics 13:1325 (1967).
(*3*) SHLEIEN, B. and P. J. MAGNO. Plutonium concentrations in ground level air and changes in plutonium–238 to plutonium–239 ratios. Radiol Health Data Rep 8:561 (1967).
(*4*) VOLCHOK, H. L. and M. T. KLAINMAN. Strontium–90 in surface air, 1963–1967. HASL–204:17 (January 1969).
(*5*) VOLCHOK, H. L. Fallout of plutonium–238 from the SNAP–9A burnup IV. HASL–207:5 (April 1969).
(*6*) DEBORTOLI, M. C. and P. GAGLIONE. SNAP–9A plutonium–238 fallout in Ispra, Italy. Health Physics 16:197 (February 1969).
(*7*) SHLEIEN, B. An evaluation of internal radiation exposure based on dose commitments from radionuclides in milk, food, and air, presented at the 14th annual meeting, Health Physics Society, Pittsburgh, Pa (June 1969).
(*8*) The "Summary of Reported Atmospheric Detonations and Vents" was compiled by the authors from data published in *Radiol Health Data Rep* 1 month following the public announcement of an event by the Atomic Energy Commission.
(*9*) TELEGADAS, K. The seasonal strotospheric distribution of plutonium–238 and strontium–90, March through November 1967. HASL–204:2 (January 1969).
(*10*) THOMAS, C. W. Concentration of airborne radioactivity during 1968. BNWL–1051:85 (June 1969).
(*11*) HARDY, E. Strontium–90 ratios in monthly fallout: some qualitative observations. HASL–200:28 (October 1968).
(*12*) WEAVER, L. E., P. O. STROM, and P. A. KILLEEN. Estimated total chain and independent fission yields for several neutron-induced fission processes. USNRDL–TR–633 (March 1963).
(*13*) PERSSON, G. and J. SISEFSKY. Debris from the 6th Chinese nuclear test. Nature 233:173 (July 1969).
(*14*) VOLCHOK, H. L. Worldwide distribution of strontium–90 through 1968. HASL–210:2 (July 1969).
(*15*) VOLCHOK, H. L. The anticipated distribution of ^{109}Cd and ^{238}Pu (from SNAP–9A) based on ^{102}Rh tracer experience. HASL–165:312 (January 1966).

Technical Notes

Lead Content of Glass Used for Shielding Television Receiver Components and its Relation to Exposure Rate

Harry Levine and *Paul S. Ruggera*[1]

The amount and type of elements of high atomic number in the glass envelopes of certain types of television tubes and x-ray fluoroscopic screens are known to influence the transmission of x rays into the environment. Emissions of x radiation, sometimes exceeding the National Council on Radiation Protection and Measurements (NCRP) recommendations (*1*), have been found to originate from picture tubes, shunt regulator tubes, and high voltage rectifier tubes, particularly under some conditions of operation and construction (*2*).

When conducting inspections of equipment where the transmission of x radiation is in question, it is useful for the inspector to know the lead content of the glass so that its ability to absorb x rays may be estimated. It is desirable, for example, to detect the substitution of non-leaded glass for original or replacement tubes or fluoroscopic screens, and sometimes to check the manufacturer's statement of lead composition.

A rapid, semiquantitative method for the estimation of lead in glass has been developed and has been described in detail elsewhere (*3*). The method is based on the action of a mixture of hydrofluoric acid and sodium iodide and is applicable to glass and ceramics (*4*). An important feature of the test is that the reaction can be performed in a matter of minutes in the field, without causing visible damage to the specimen.

Table 1 presents a comparison of the estimated amount of lead using the "reagent drop method" and the amount determined by conventional methods in various glass specimens.

Table 1. A comparison of lead content in glass specimens determined by conventional methods and by the reagent drop method

Sample identification	Determination by conventional methods (percent PbO)	Approximate estimation by reagent drop method (percent PbO)
Corning glass tube envelope (E-1)	[a] 26.47	25
Corning glass tube envelope (E-2)	[a] Trace	0
#3720 TV picture tube safety panel (SP-1)	[a] 0	0
#3755 or 3770 TV picture tube safety panel (SP-2)	[a] 4.87	5
Corning 9019 TV picture tube face plate	[a] Trace	0
G.E. 6EH4 (GEH-020)	[b] 30.32	30
G.E. 6EL4 (OWE-006)	[b] 30.52	30
Syl. 6BK4C (EMP-006)	[b] 50.06	50
G.E. 6EL4 (OWE-117) new type	[b] 50.35	50

[a] Determined gravimetrically (*5*).
[b] Determined by atomic absorption spectrophotometry (*6*).

Several shunt regulator tubes, both of the earlier and the more recent version, were investigated to evaluate the usefulness of the rapid method in determining a relative correspondence between the amount of lead present in a glass envelope and the resultant x-ray emission from the tube. The tubes were used to expose four 14- by 17-inch film packs made up of a KK type and a commercial type film 22 (Eastman Kodak type S0142, Type S0125, Duo-Ready Pack, Rochester, New York). The film pack was formed into a 17-inch high cylinder, which, when placed around the tube was approximately 5 cm from the tube center line. Exposure was made at 30,000 volts and 0.5 milliamperes for a period of 6 hours. The film was then developed under controlled conditions (new chemicals, constant temperature, gas-burst agitation), so that the exposure rate could be determined using a densitometer and a set of calibration curves which relate density to exposure rate. The calibration of the film pack was performed with a free air ion chamber.

[1] Messrs. Levine and Ruggera are with the Division of Electronic Products, Bureau of Radiological Health, Environmental Health Service, Rockville, Md. 20852.

Table 2. Relative comparison between lead content of glass envelope and resultant exposure rate

Tube type	Average envelope thickness (in.)	Average lead content: Chemical analysis (percent PbO)	Average lead content: Fast method (percent PbO)	Average net density of film	Average dose rate (mR/h)
G.E. 6EH4 GEH-020	0.035	30.32	30	3.78	11.7
G.E. 6EL4 OWE-006	.050	30.52	30	1.10	3.33
Syl. 6BK4C EMP-006	.034	50.06	50	.12	.30
New G.E. 6EL4 OWE-117	.047	50.35	50	.01	[a].04

[a] This value was determined by extrapolation of the calibration curve.

Table 2 presents a comparison between the amount of lead present in the glass envelope and its associated exposure rate. Increasing the lead content between the two, thinner glass envelopes of tubes 6EH4 and 6BK4C reduced the exposure rate by a factor of 40. The other variable, the wall thickness of the envelope, also had some effect. Comparing the 6EH4 with the 6EL4, a reduction factor of 3.5 is observed. Cross comparisons with the new 6EL4 were not made since a density of 0.01 is not a point on the calibration curve. The exposure rate was therefore estimated by extrapolating the curve to that value.

In summary, the field test for lead content of the shunt regulator tube could be a valuable tool in field surveys of sets found to emit excessive radiation. When a field of radiation is detected in the area of the shunt regulator tube, the investigator cannot be sure of the exact source since it could be the shunt, the high-voltage rectifier, or the picture tube. Using the test kit, he can determine, with relative certainty, the lead content of the shunt regulator tube. If the tube contained approximately 50 percent PbO, then it could be eliminated as the defective component. This leaves the high voltage rectifier, which is always in a metal cage for voltage protection, and the picture tube. Since instrumentation is available by which one can determine the beam area, the elimination of the shunt regulator tube from consideration will almost certainly pinpoint the defective component. The picture tube will most probably have a large area beam, whereas the high voltage rectifier would emit a beam only through the air holes in the cage and, therefore, be much smaller in area. A similar set of criteria can be established for components other than the shunt regulator tube to determine the relative comparison of x-ray transmission to lead content.

The use of trade names mentioned in this manuscript does not imply endorsement by the U.S. Public Health Service.

REFERENCES

(1) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. National Council on Radiation Protection and Measurements. Radiology 75:122 (1960).
(2) STEWART, H. F., N. F. MODINE, E. G. MURPHY, and J. W. ROLOFSON. X-ray patterns and intensities from high voltage shunt regulator tubes for color television receivers. Radiol Health Data Rep 8:675–686 (December 1967).
(3) LEVINE, H. and P. S. RUGGERA. A Field Method for the Determination of Lead in Glass Used for Shielding Television Receiver Components. PHS, Bureau of Radiological Health, Division of Electronic Products Report 69–2 (September 1969).
(4) KING, J. Museums Journal, Vol. 56 (March 1957).
(5) FISHER, G. E. Analysis of Glass. Scott's Standard Methods of Chemical Analysis, Fifth Edition, Vol. 2, pp 2164–2174.
(6) JONES, A. H. Analysis of glass and ceramic frit by atomic absorption spectrophotometry. Anal Chem 37: 1761 (1965).

Tritium Concentration in Precipitation, 1967-1968

A. A. Moghissi and *C. R. Porter*[1]

Since the discovery of natural tritium (*1–2*), rain has been extensively monitored to study the production and behavior of this radionuclide in the hydrological cycle (*3*). Although the methodology of early tritium studies (*4*) proved to be somewhat unreliable (*5*), these findings are the basis of our present knowledge regarding the natural concentration and seasonal variation of tritium.

It has been well established that under normal conditions—i.e., in the absence of the introduction of tritium by nuclear bomb testing—tritium concentration in rain will increase during spring and late summer in the Northern Hemisphere (*3*). In the Southern Hemisphere the conditions are similar, although less pronounced (*3*).

Because of the mode of production of natural tritium (*1–3*), it may be expected that the tritium concentration will increase in higher altitudes. Also, numerous studies have shown that tititum concentrations reach a maximum at 45–60° N latitude in the Northern Hemisphere (*3*). There is presently no adequate explanation for this phenomenon.

Rain analysis represents a sensitive technique for monitoring of tritium in the environment. Any significant addition of tritium into the natural cycle can easily and rapidly be detected by rain analysis, primarily due to considerable improvements in the low-level counting techniques for tritium (*6*).

[1] Dr. Moghissi was at Southeastern Radiological Health Laboratory, Montgomery, Ala. and now is with Southwestern Radiological Health Laboratory, Las Vegas, Nev. 89114. C. R. Porter is director, Southeastern Radiological Health Laboratory, Montgomery, Ala. 36101.

Beginning in 1967, the Bureau of Radiological Health established a tritium in rain network as part of the existing Radiation Alert Network. Ten stations were selected covering the United States, including Alaska and the Hawaiian Islands. The locations of these stations are shown in figure 1.

Procedure

Rain samples from the collection sites are shipped to Rockville, Md., where they are composited on a monthly basis. Part of each monthly composite is transferred to disposable containers and shipped to the Southeastern Radiological Health Laboratory where they are distilled and counted by a liquid scintillation technique. The details of the analytical procedure have been described elsewhere (*7*). It consists of the addition of 20 ml of a scintillation liquid to 5 ml of water in a plastic vial. The scintillation liquid consists of spectrographic grade dioxane containing 7 g diphenyloxazole (PPO), 1.5 g *p*-bis-(o-methylstryl)-benzene(bis-MSB), and 120 g naphthalene per liter. All operations involving the scintillation solution are carried out under red light. Plastic vials, manufactured by Nuclear Chicago Corporation, and a Beckman liquid scintillation counter are used. Under these conditions, a counting efficiency of 22.5 percent was obtained with a background of 8.0 cpm resulting in a sensitivity of 0.40 nCi/liter-cpm.

Duplicate samples were prepared and counted twice for 50 minutes. A background sample was counted before the first sample and a second background after the duplicate sample. If any one of

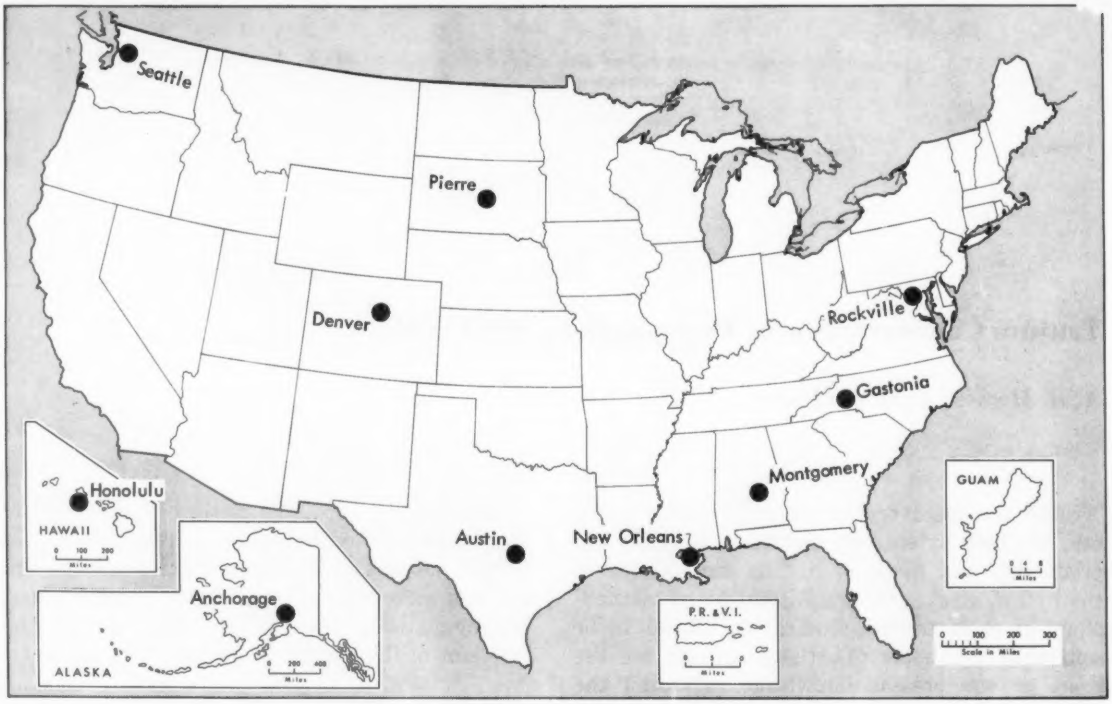

Figure 1. Tritium precipitation stations

Results

Tables 1 and 2 show the analytical results obtained from the samples collected during 1967 and

the 50-minute sample counts deviated by more than 2-sigma from the average, the duplicates were recounted. This occurred, however, with a frequency comparable to the statistical expectation. The error of the analysis at the 2-sigma confidence level as a function of activity is shown in figure 2. The minimum limit of detection was 0.2 nCi/liter at the 2-sigma confidence level.

The results of this investigation are indicative of radiological health implications of tritium in the atmosphere. It can be clearly seen that tritium in the atmosphere is continuously decreasing as compared to 1965 samples (*3*). Tritium concentrations in rain for previous years are not available from the same geographical locations of this investigation. It is, however, interesting to consider that levels as high as 6 nCi/liter were reported for the continental United States during 1965.

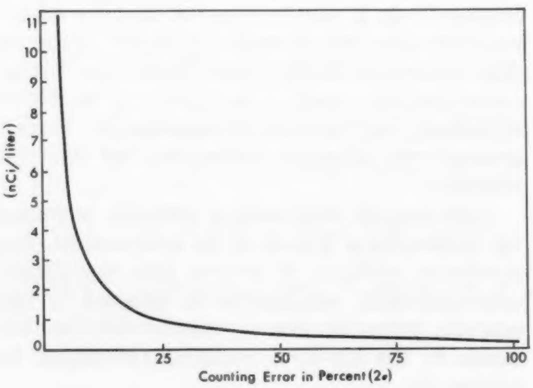

Figure 2. Correlation between tritium concentration of water and counting error in percent at the 2-sigma confidence level

Table 1. Tritium analysis of rain composites from RAN stations, 1967

Location	Concentration (nCi/liter)											
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
N.C. Gastonia	0.2	0.5	0.5	0.6	0.8	0.2	0.3	<0.2	0.8	<0.2	<0.2	0.3
Md. Rockville	([a])	.6	.7	1.0	.7	.5	([a])	([a])	([a])	<.2	<.2	<.2
Ala. Montgomery	([a])	.5	<.2	([a])	([a])	<.2	<.2	([a])	.9	1.2	<.2	<.2
S.Dak. Pierre	([a])	([a])	([a])	2.0	2.1	1.3	([a])	([a])	<.2	([a])	([a])	([a])
La. New Orleans	<.2	<.2	.4	<.2	<.2	<.2	.3	<.2	.4	<.2	<.2	<.2
Tex. Austin	<.2	<.2	.5	<.2	<.2	([a])	<.2	<.2	<.2	<.2	<.2	<.2
Colo. Denver	.5	1.0	1.1	2.6	1.7	1.4	1.4	1.1	1.2	.3	.5	.4
Hawaii Honolulu	<.2	.2	.2	.4	<.2	([a])	<.2	<.2	1.4	.3	<.2	<.2
Wash. Seattle	<.2	.4	.7	.6	.7	.5	([a])	([a])	1.6	<.2	<.2	<.2

[a] Sample not received.

Table 2. Tritium analysis of rain composites from RAN stations, 1968

Location	Concentration (nCi/liter)											
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
N.C. Gastonia	0.4	<0.2	<0.2	0.5	0.2	0.5	<0.2	([a])	<0.2	<0.2	<0.2	<0.2
Md. Rockville	<.2	([a])	<.2	([a])	([a])	([a])	([a])	<0.2	([a])	<.2	([a])	([a])
Ala. Montgomery	<.2	<.2	.3	.5	.2	.5	<.2	<.2	<.2	<.2	<.2	<.2
Alaska Anchorage	([a])	([a])	([a])	([a])	.5	.5	.7	.7	<.2	<.2	([a])	<.2
La. New Orleans	.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	([a])	([a])	([a])
Tex. Austin	<.2	.9	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	([a])
Colo. Denver	.4	1.1	.5	1.7	1.2	.6	.5	.4	.6	<.2	.5	([a])
Hawaii Honolulu	<.2	<.2	<.2	<.2	([a])	<.2	([a])	([a])	.5	([a])	<.2	([a])
Wash. Seattle	.2	<.2	<.2	<.2	.3	<.2	<.2	.3	<.2	<.2	<.2	<.2

[a] Sample not received.

1968. The station at Montgomery, Ala., is not a sample collection site; but due to the availability of this sample, it was run for comparison.

The spring and late summer peaks are clearly detectable in the majority of cases. The station with the highest tritium level is Denver, Colo. Figure 3 shows the tritium concentration of rain samples during the entire sampling period from this station. The reason for the relatively high levels of tritium in rain from Denver is attributed primarily to the high altitude of this location.

The effect of latitude is shown in samples collected from Pierre, S. Dak., from which, unfortunately, only three samples were received. This was the only station within the 45–60° N latitude that

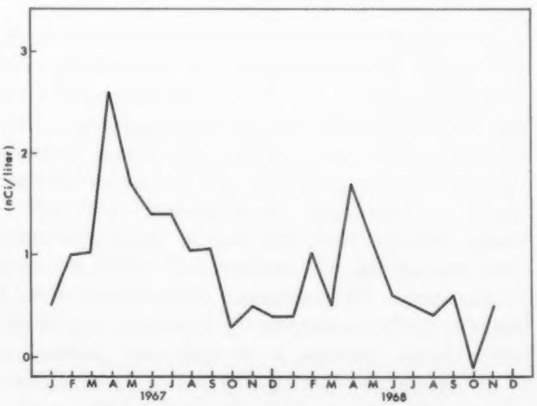

Figure 3. Tritium activity of precipitation in Denver, Colo., during 1967–1968

would not be affected by dilution from ocean evaporation.

The analysis of samples received during the last 2 months of the sampling period reported was carried out using a suspension technique (*8*) with a minimum limit of detection of 0.1 nCi/liter. As this was in an experimental state and for the sake of uniformity, these values are reported to the same sensitivity as the previously used method.

The analytical technique used, although a sensitive method, is inadequate for any geophysical prediction. An adequate technique for the observation of tritium concentration in rain for this purpose would require a minimum limit of detection of 10–20 pCi/liter of water.

Acknowledgment

The technical assistance of Mae W. Williams and Rachael H. Gorrie in the preparation of this paper is greatly appreciated.

REFERENCES

(*1*) FALTING, V. and P. HARDECK. Tritium content of the atmosphere. Z Naturforsch 5a:438 (1950).

(*2*) GROSSE, A. V., W. H. JOHNSTON, R. L. WOLFGANG, and W. F. LIBBY. Tritium in nature. Science 113:1 (1951).

(*3*) INTERNATIONAL ATOMIC ENERGY AGENCY. Tritium and Other Environmental Isotopes in the Hydrological Cycle, Technical Report No. 73. International Atomic Energy Agency, Vienna (1967).

(*4*) KAUFMAN, S. and W. F. LIBBY. Natural distribution of tritium. Phys Rev 93:1337 (1954).

(*5*) SCHUMACHER, E. Methodology for tritium in natural waters. Helv Chim Acta 43:1019 (1960).

(*6*) MOGHISSI, A. A. Radionuclides in the Environment. Analysis and Public Health Aspects of Environmental Tritium. Advances in Chemistry Series, American Chemical Society, Washington, D.C. (in press).

(*7*) MOGHISSI A. A. H. L. Kelley, J. E. REGNIER and M. W. CARTER. Low-level counting by liquid scintillation. 1. Tritium measurement in homogeneous systems. Inter J Appl Rad Isotopes 20:145 (1969).

(*8*) LIEBERMAN, R. and A. A. MOGHISSI. Low-level counting by liquid scintillation. 2. Application of emulsions in tritium measurements. Inter J Appl Rad Isotopes (in press).

Data

SECTION I. MILK AND FOOD

Milk Surveillance, November 1969

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Compliance, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by those several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in or are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk.

The five fission-product radionuclides which commonly occur in milk are strontium–89, strontium–90, iodine–131, cesium–137, and barium–140. A sixth radionuclide, potassium–40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium–40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and

Figure 1. Milk sampling networks in the Western Hemisphere

radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations, for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted in the period, July–September 1969, with 31 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. Of the 19 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 15 participated in the experiment.

The iodine-131 and cesium-137 results show much improvement over previous tests. Barium-140 results also look good which is encouraging, since this is the first time barium-140 was analyzed for this type of experiment. However, strontium-89 and strontium-90 analyses still need improvement (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A recent article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collected and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks, but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical, and is generally increased at the first measurement or recognition of a new influx of the radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during the period, January 1964 to June 1966, indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are

not statistically significant. Particular attention was paid to strontium–90 and cesium–137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (*3*). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium–89	5
Strontium–90	2
Iodine–131	10
Cesium–137	10
Barium–140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurement equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium–89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥ 50 pCi/liter
Strontium–90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥ 20 pCi/liter
Iodine–131, Cesium–137, Barium–140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥ 100 pCi/liter

For iodine–131, cesium–137, and barium–140 there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8, 9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result from exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Radionuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day)[b]	Range II (pCi/day)[b]	Range III (pCi/day)[b]
Strontium-89	Bone	[c]1.5	0.5	[d]2,000	0-200	200-2,000	2,000-20,000
	Bone marrow	[c].5	.17				
Strontium-90	Bone	[c]1.5	.5	[d]200	0-20	20-200	200-2,000
	Bone marrow	[c].5	.17				
Iodine-131	Thyroid	1.5	.5	100	0-10	10-100	100-1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0-360	360-3,600	3,600-36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.
[b] Based on an average intake of 1 liter of milk per day.
[c] A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.
[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.
[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

Protective Action Guides *(10, 11)*

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier *(3)*. Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which if attained after an acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk) Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c]1,110,000
Strontium-90	Bone marrow			[c]51,000
Cesium-137	Whole body			[c]720,000
Iodine-131	Thyroid	30	10	[d]70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.
[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.
[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.
[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

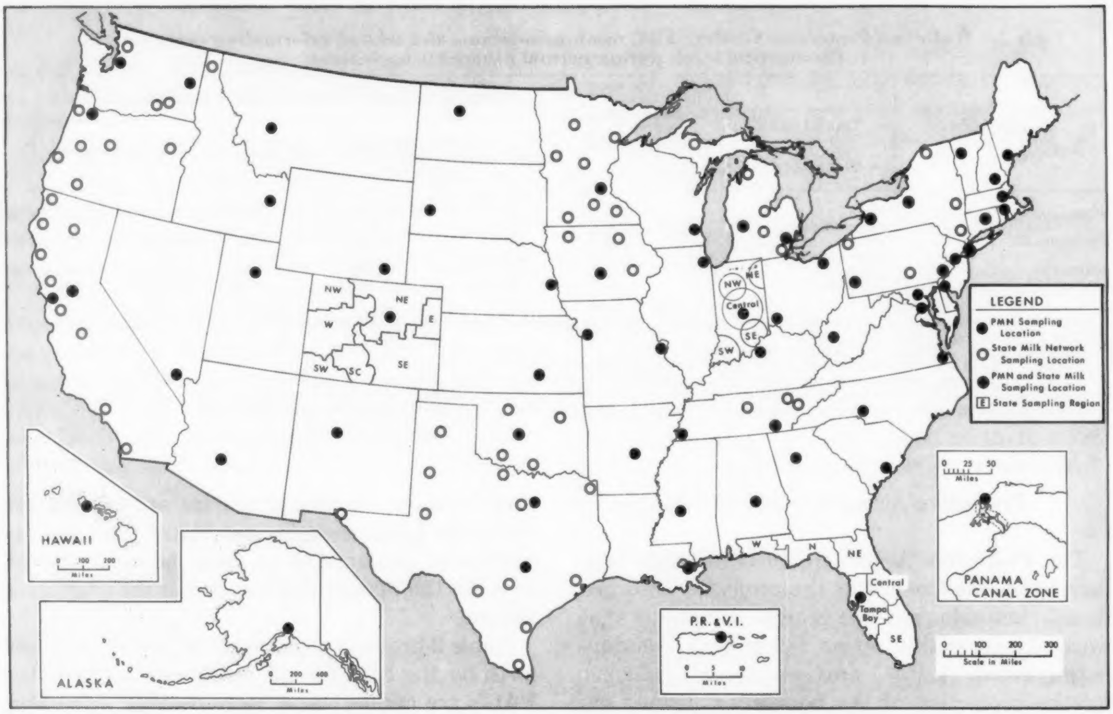

Figure 2. State and PMN milk sampling locations in the United States

pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2). The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12-monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium–90, iodine–131, and cesium–137, for November 1969 and the 12-month period, December 1968 to November 1969. Except where noted, the monthly average represents a single sample for the sampling station. Strontium–89 and barium–140 data have been omitted from table 3 since levels at the great majority of the stations for November 1969 were below the respective practical reporting levels, with the exception of the stations given in table 4.

Table 3. Concentrations of radionuclides in milk for November 1969 and 12-month period, December 1968 through November 1969

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:								
Ala:	Montgomery[c]	P	9	7	0 (4)	0	13 (4)	10
Alaska:	Palmer[c]	P	6	6	0 (4)	0	6 (4)	6
Ariz:	Phoenix[c]	P	0	1	0 (4)	0	0 (4)	0
Ark:	Little Rock[c]	P	14	17	0 (4)	0	18 (4)	18
Calif:	Sacramento[c]	P	0	1	0 (4)	0	0 (4)	0
	San Francisco[c]	P	0	2	0 (4)	0	0 (4)	0
	Del Norte	P	20	19	0	0	3	1
	Fresno	P	11	0	0	0	6	0
	Humboldt	P	4	5	0	0	4	8
	Los Angeles	P	2	2	0	0	5	3
	Mendocino	P	3	4	0	0	4	5
	Sacramento	P	2	3	0	0	5	6
	San Diego	P	2	2	0	0	4	4
	Santa Clara	P	1	2	0	0	0	6
	Shasta	P	3	3	0	0	4	7
	Sonoma	P	2	3	0	0	6	6
Colo:	Denver[c]	P	5	5	0 (4)	0	0 (4)	1
	West	R	(d)		NS	(e)	NS	(e)
	Northeast	R	(d)		(e)	(e)	(e)	(e)
	East	R	(d)		(e) (2)	(e)	(e)	(e)
	Southeast	R	(d)		NS	(e)	(e)	(e)
	South central	R	(d)		NS	(e)	NS	(e)
	Southwest	R	(d)		NS	(e)	NS	(e)
	Northwest	R	(d)		(e)	(e)	(e)	(e)
Conn:	Hartford[c]	P	6	8	NS	(e)	NS	(e)
	Central	P	5	7	0 (4)	0	10 (4)	12
Del:	Wilmington[c]	P	7 (4)	9	0 (4)	0	7 (4)	10
D.C:	Washington[c]	P	7	7	0 (4)	0	0 (4)	6
Fla:	Tampa[c]	P	7	7	0 (4)	0	9 (4)	5
	West	R	12	11	0 (2)	0	51 (2)	56
	North	R	9	14	0	0	33	27
	Northeast	R	8	6	0	0	31	29
	Central	R	8	7	0	0	44	59
	Tampa Bay area	R	8	8	0	0	27	58
	Southeast	R	12	8	0	0	45	59
Ga:	Atlanta[c]	P	7	10	0	0	110	93
Hawaii:	Honolulu[c]	P	3 (4)	3	0 (4)	0	19 (4)	19
Idaho:	Idaho Falls[c]	P	5	5	0 (4)	0	0 (4)	0
Ill:	Chicago[c]	P	7	8	0 (4)	0	6 (4)	6
Ind:	Indianapolis[c]	P	10	8	0 (4)	0	6 (4)	10
	Northeast	P	9	12	0 (4)	0	5 (4)	6
	Southeast	P	10	8	0	0	15	10
	Central	P	9	9	0	0	10	12
	Southwest	P	11	10	0	0	10	10
	Northwest	P	11	10	0	0	10	12
Iowa:	Des Moines[c]	P	6	5	0	0	20	16
	Iowa City	P	NS		0 (4)	0	7 (4)	2
	Des Moines	P	NS		NS		NS	
	Spencer	P	NS		NS		NS	
	Fredericksburg	P	NS		NS		NS	
Kans:	Wichita[c]	P	9	7	NS		NS	
Ky:	Louisville[c]	P	6	9	0 (4)	0	0 (4)	2
La:	New Orleans[c]	P	11	16	0 (4)	0	6 (4)	5
Maine:	Portland[c]	P	11	12	0 (2)	0	19 (2)	19
Md:	Baltimore[c]	P	8	8	0 (4)	0	20 (4)	23
Mass:	Boston[c]	P	9	11	0 (4)	0	3 (4)	6
Mich:	Detroit[c]	P	8	8	0 (4)	0	20 (4)	21
	Grand Rapids[c]	P	9	10	0 (4)	0	7 (4)	9
	Bay City	P	NA	7	0 (4)	0	8 (4)	14
	Charlevoix	P	NA	9	0	0	0	8
	Detroit	P	NA	6	0 (4)	0	16 (4)	16
	Grand Rapids	P	NA	8	0 (4)	0	9 (4)	6
	Lansing	P	NA	6	0 (4)	0	12 (4)	12
	Marquette	P	NA	10	0 (2)	0	16 (2)	11
	Monroe	P	NA	5	0 (2)	1	21 (2)	28
	South Haven	P	NA	7	0 (2)	1	6 (2)	2
Minn:	Minneapolis[c]	P	12	10	0	0	NS	8
	Bemidji	P	16	17	0 (4)	0	4 (4)	10
	Mankato	P	7	9	0	0	20	24
	Rochester	P	8	8	0	0	16	0
	Duluth	P	17	19	0	0	0	0
	Worthington	P	7	8	0	0	16	23
	Minneapolis	P	9	12	0	0	0	0
	Fergus Falls	P	11	10	0	0	0	0
	Little Falls	P	9	10	0	0	0	0
Miss:	Jackson[c]	P	9	12	0	0	11	11
Mo:	Kansas City[c]	P	5	7	0 (4)	0	10 (4)	14
	St. Louis[c]	P	11	8	0 (3)	0	0 (3)	1
Mont:	Helena[c]	P	4	5	0 (4)	0	3 (4)	2
Nebr:	Omaha[c]	P	6	6	0 (4)	0	2 (4)	6
Nev:	Las Vegas[c]	P	0	1	0 (4)	0	0 (4)	2
N.H:	Manchester[c]	P	6	8	0 (4)	0	0 (4)	0
N.J:	Trenton[c]	P	8	9	0 (4)	0	19 (4)	20

See footnotes at end of table.

Table 3. Concentrations of radionuclides in milk for November 1969 and 12-month period, December 1968 through November 1969—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued								
N.Mex:	Albuquerque[c]	P	3	2	0 (4)	0	0 (4)	1
N.Y:	Buffalo[c]	P	6	7	0 (4)	0	12 (4)	10
	New York City[c]	P	9	10	0 (4)	0	14 (4)	13
	Syracuse[c]	P	5	8	0 (4)	0	13 (4)	9
	Albany	P	5	6	0 (3)	0	(e) (2)	(e)
	Buffalo	P	(e)	(e)	0	0	(e)	(e)
	Massena	P	5	9	0	0	(e)	(e)
	Newburg	P	11	10	0	0	(e)	(e)
	New York City	P	(e)	9	0 (4)	0	(e) (4)	(e)
	Syracuse	P	(e)	7	0 (2)	0	(e) (2)	(e)
N.C:	Charlotte[c]	P	9	13	0 (4)	0	14 (4)	12
N.Dak:	Minot[c]	P	9	10	0 (4)	0	11 (4)	13
Ohio:	Cincinnati[c]	P	7	8	0 (4)	0	7 (4)	3
	Cleveland[c]	P	8	9	0 (4)	0	3 (4)	7
Okla:	Oklahoma City[c]	P	3	8	0 (2)	0	0 (2)	9
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Ore:	Portland[c]	P	7	7	0 (4)	0	6 (4)	6
	Baker	P	NA	2	(e)	(e)	NA	9
	Coos Bay	P	5	5	(e)	(e)	18	12
	Eugene	P	3	4	(e)	(e)	(e)	8
	Medford	P	NA	2	(e)	(e)	(e)	17
	Portland composite	P	4	3	(e)	(e)	13 (4)	6
	Portland local	P	5	5	(e)	(e)	(e) (4)	9
	Redmond	P	0	1	(e)	(e)	(e)	4
	Tillamook	R	3	6	(e)	(e)	(e)	19
Pa:	Philadelphia[c]	P	9	9	0 (4)	0	4 (4)	5
	Pittsburgh[c]	P	9	12	0 (4)	0	9 (4)	8
	Dauphin	P	5	6	0	1	20	14
	Erie	P	8	10	0	6	27	20
	Philadelphia	P	6	8	18	3	15	10
	Pittsburgh	P	6	10	0	2	16	17
R.I:	Providence[c]	P	8	9	0 (4)	0	14 (4)	16
S.C:	Charleston[c]	P	11	11	0 (3)	0	22 (3)	23
S.Dak:	Rapid City[c]	P	7	8	0 (2)	0	7 (2)	6
Tenn:	Chattanooga[c]	P	7	10	0 (4)	0	15 (4)	13
	Memphis[c]	P	6	8	0 (4)	0	7 (4)	5
	Chattanooga	P	11	13	0 (4)	0	5 (4)	15
	Clinton	P	12	15	0 (2)	0	12 (2)	14
	Knoxville	P	10	10	0 (2)	0	6 (2)	7
	Nashville	P	7	9	0 (2)	0	5 (2)	5
Tex:	Austin[c]	P	0	2	0 (4)	0	4 (4)	4
	Dallas[c]	P	4	6	0 (4)	0	6 (4)	6
	Amarillo	R	NS	4	NS	0	NS	0
	Corpus Christi	R	4	4	0	0	0	0
	El Paso	R	7	2	0	0	0	0
	Fort Worth	R	NS	5	NS	0	NS	2
	Harlingen	R	NS	2	NS	0	NS	0
	Houston	R	NS	6	NS	0	NS	11
	Lubbock	R	5	4	0	0	0	0
	Midland	R	NS	3	NS	0	NS	0
	San Antonio	R	NS	3	NS	0	NS	0
	Texarkana	R	NS	11	NS	0	NS	15
	Uvalde	R	3	2	0	0	0	0
	Wichita Falls	R	6	6	0	0	10	8
Utah:	Salt Lake City[c]	P	4	4	0 (4)	0	0 (4)	5
Vt:	Burlington[c]	P	7	8	0 (4)	0	12 (4)	14
Va:	Norfolk[c]	P	9	10	0 (4)	0	12 (4)	8
Wash:	Seattle[c]	P	7	7	0 (4)	0	6 (4)	12
	Spokane[c]	P	7	7	0 (4)	0	4 (4)	5
	Benton County	R	0	1	(d)		13	4
	Franklin County	R	NS	2	(d)		NS	0
	Sandpoint, Idaho	R	11	11	(d)		33	28
	Skagit County	R	5	7	(d)		0	14
W.Va:	Charleston[c]	P	7	9	0 (4)	0	9 (4)	7
Wisc:	Milwaukee[c]	P	7	7	0 (4)	0	8 (4)	11
Wyo:	Laramie[c]	P	6	5	0 (4)	0	0 (4)	7
CANADA:								
Alberta:	Calgary	P	10	8	(d)		16	15
	Edmonton	P	6	7	1		14	14
British Columbia:	Vancouver	P	10	11	(d)		22	33
Manitoba:	Winnipeg	P	8	8	(d)		24	25
New Brunswick:	Frederickton	P	12	13	(d)		12	18
Newfoundland:	St. Johns	P	16	17	(d)		22	35

See footnotes at end of table.

Table 3. Concentrations of radionuclides in milk for November 1969 and 12-month period, December 1968 through November 1969—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium–90		Iodine–131		Cesium–137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued								
Nova Scotia:								
	Halifax	P	12	10	([d])		15	20
Ontario:	Ft. William	P	15	16	([d])		34	31
	Ottawa	P	7	9	([d])		9	15
	Sault Ste. Marie	P	14	15	([d])		28	30
	Toronto	P	4	5	([d])		10	11
	Windsor	P	4	5	([d])		10	12
Quebec:	Montreal	P	8	9	([d])		17	18
	Quebec	P	10	11	([d])		22	26
Saskatchewan:								
	Regina	P	8	7	([d])		17	12
	Saskatoon	P	7	8	([d])		10	13
CENTRAL AND SOUTH AMERICA:								
Columbia:	Bogota	P	0	1	0	0	0	1
Chile:	Santiago	P	0	0	0	0	0	1
Ecuador:	Guayaquil	P	0	0	0	0	0	0
Jamaica:	Mandeville	P	4	5	0	0	95	95
Venezuela:	Caracas	P	0	1	0	0	0	0
Canal Zone:	Cristobal[c]	P	0	1	0 (4)	0	12 (4)	11
Puerto Rico:	San Juan[c]	P	0	3	0 (4)	0	8 (4)	7
PMN Network average[f]			7	8	0	0	8	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or national network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine–131:	Colorado—25 pCi/liter	Cesium–137:	Colorado—25 pCi/liter
	Michigan—14 pCi/liter		New York—20 pCi/liter
	Oregon—15 pCi/liter		Oregon—15 pCi/liter

[f] This entry gives the average radionuclide concentrations for the PHS Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample.

Iodine–131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine–131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium–90 monthly averages ranged from 0 to 20 pCi/liter in the United States for November 1969, and the highest 12-month average was 19 pCi/liter (Del Norte, Calif., Duluth, Minn.) representing 9.5 percent of the Federal Radiation Council radiation protection guide (table 1). Cesium–137 monthly averages ranged from 0 to 110 pCi/liter in the United States for November 1969 and the highest 12-month average was 93 pCi/liter (southeast Fla.), representing 2.6 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium–137 levels that have been observed in Florida (*12*) and Jamaica. Iodine–131 monthly averages were generally below the practical reporting level, with the following exception: Philadelphia, Pa. (State) 18 pCi/liter.

Table 4. Strontium–89 in milk, November 1969

Sampling location		Radionuclide concentration (pCi/liter)
		Strontium–89
Calif:	Del Norte (State)	10
Mo:	Kansas City (PMN)	7
N.Dak:	Minot (PMN)	11
Okla:	Oklahoma City (PMN)	8

Acknowledgment

Appreciation is expressed to the personnel of the following health agencies who provide data fo their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational, and Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Division of Radiological Health
Bureau of Preventable Diseases
Florida State Board of Health

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

REFERENCES

(1) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER, and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Public Health 49:225 (February 1959).

(2) Chart of the Nuclides, Ninth Edition revised to July 1966. Knolls Atomic Power Laboratory (November 1966).

(3) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(4) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(5) KNOWLES, F. Interlaboratory study of iodine-131, cesium-137, barium 140, strontium-89, and strontium-90 measurements in milk, July–September 1969, Technical experiment 69, MKAQ-2. Analytical Quality Control Service, Bureau of Radiological Health (October 1969).

(6) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radiol Health Data Rep 8:621–627 (November 1967).

(7) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

(8) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(9) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(10) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(11) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action guides for strontium-89, strontium-90, and cesium-137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(12) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The Cause of Relatively High Cesium-137 Concentrations in Tampa, Florida Milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25–29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95–101.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionnclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Issue
California Diet Study	November 1967–September 1968	May 1969
Connecticut Diet Study	July–December 1968 and January–June 1969	February 1970
Radionuclides in Institutional Diet Samples, *PHS*	April–June 1969	January 1970
Strontium-90 in Tri-City Diets, *HASL*	August–December 1968	December 1969

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposure greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below:

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	January–June 1968	December 1969
Coast Guard Water Supplies	January 1968–July 1969	February 1970
Colorado River Basin	1967	December 1968
Minnesota	January–June 1969	January 1970
New York	July–December 1968	September 1969
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, *HASL*	July–December 1968	November 1969
Washington	July 1967–June 1968	June 1969

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in Florida Waters, 1968

Division of Radiological Health
Florida State Board of Health

The Florida State Board of Health samples raw surface, ground, and treated water in 13 hydrological subbasins as shown in figure 1. Samples collected on a variable frequency and analyzed for gross alpha and beta radioactivity during 1968 are presented in table 1. Gross alpha and gross beta radioactivity concentrations of less than 7 pCi/liter and less than 10 pCi/liter, respectively, are not reported.

[1] Data taken from "Report of Florida Radiological Surveillance Programs, 1968" Bureau of Preventable Diseases, Division of Radiological Health, Jacksonville, Fla.

In addition to sampling being done by the Florida State Board of Health, the Bioenvironmental Engineering Research Laboratory, University of Florida, samples surface, ground and municipal water in Alachua County for gross beta radioactivity. Samples are taken monthly from each sampling point with the exception of the City of Gainesville where raw water is sampled daily. These data for 1968 are summarized in table 2. Gross beta radioactivity above the minimum reported concentration was detected in 35 water samples taken in Alachua County. The 35 samples averaged 13 pCi/liter of gross beta radioactivity.

Figure 1. Hydrological surface subbasins in Florida

During 1968, only eight samples out of a total of 227 collected from 120 sampling sites indicated gross beta radioactivity greater than the minimum reported concentration. The eight surface, ground, or municipal water samples averaged 17 pCi/liter. The average gross beta radioactivity in water samples is well below the limitations imposed by the standard for gross beta radioactivity in drinking water (1,000 pCi/liter) (*1*). Only one treated water sample indicated gross alpha radioactivity greater than the minimum reported concentration.

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. Public Health Service Drinking Water Standards, Revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March (1963).

Table 1. Gross alpha and beta radioactivity in Florida waters, 1968

Location subbasin	Number of samples	Alpha (pCi/liter)	Beta (pCi/liter)
Perdido-Escambia Rivers	4	7	10
	[a] 3	7	10
	[b] 1	7	24
Choctawhatchee River	12	7	10
	1	7	34
Apalachicola River	4	7	10
	[a] 3	7	10
Ochlockonee-St. Marks Rivers	5	7	10
	1	7	12
	[a] 2	7	10
	[a] 1	7	14
Suwannee River	5	7	10
	[a] 1	7	10
St. Mary's-Nassau Rivers	1	7	10
	[b] 1	7	10
St. John's River	37	7	10
	1	7	13
	1	7	15
	[a] 16	7	10
	[b] 4	7	10
	[c] 2	7	10
Withlacoochee River	9	7	10
	[b] 1	7	10
Tampa Bay area	9	7	10
	[a] 18	7	10
Peace River	2	7	10
	[a] 6	7	10
Kissimmee River	3	7	10
Florida East Coastal area	6	7	10
	[a] 7	7	10
	[c] 3	7	10
Lower Florida area	12	7	10
	2	7	13
	[a] 41	7	10
	[a] 1	9	10
	[b] 1	7	10

[a] Treated water.
[b] Well water.
[c] Raw water supply.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
Fallout in the United States and Other Areas, *HASL*	January–June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation, *PHS*	July–September 1968	February 1970

1. Radiation Alert Network
November 1969

Bureau of Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Bureau of Radiological Health officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Radiological Surveillance Branch, Division of Environmental Radiation, BRH, Rockville, Md. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique during November 1969. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting stations.

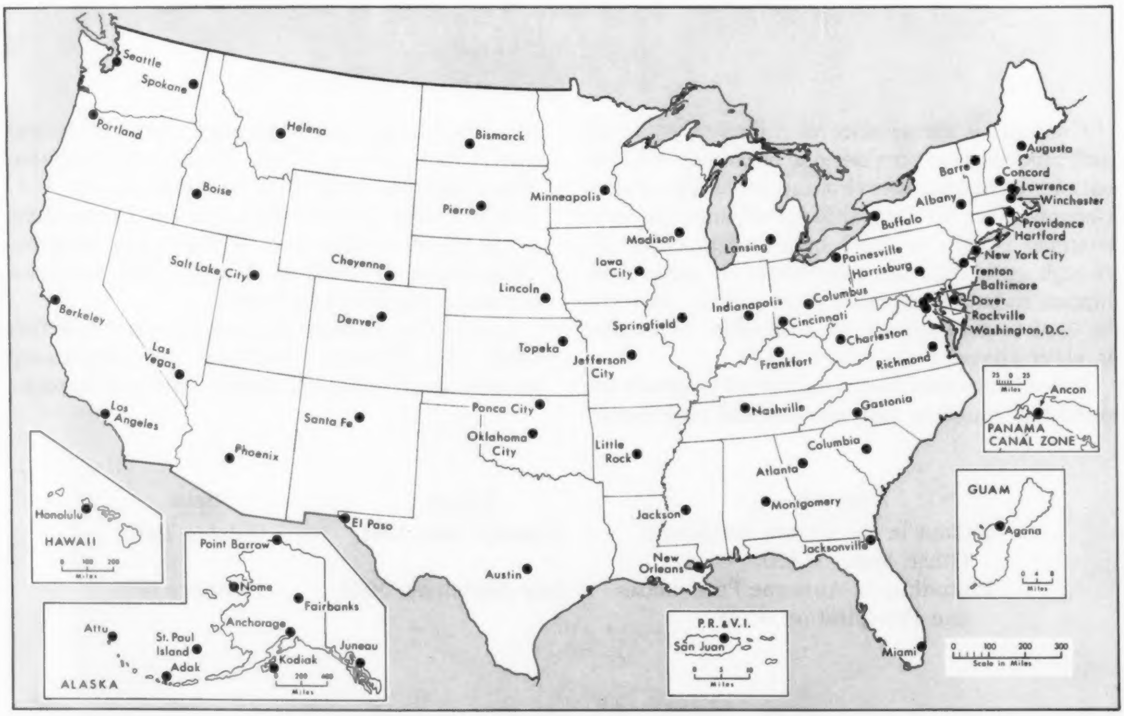

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, November 1969

Station location		Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Precipitation				
			Maximum	Minimum	Average[a]		Number of samples	Total depth (mm)	Field estimation of deposition: Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	18	7	0	4	Dec 69	3	15	3	15	0
Alaska:	Adak	17	1	0	1	Dec 69	(c)				
	Anchorage	15	0	0	0	Aug 69	(c)				
	Attu Island	15	0	0	0	Jan 70	(c)				
	Fairbanks	17	0	0	0	Sept 69	4	14	4	14	11
	Juneau	18	4	0	1	Oct 69	10	206	10	206	0
	Kodiak	8	0	0	0	Nov 69	(c)				
	Nome	27	1	0	1	Mar 70	(c)				
	Pt. Barrow	10	0	0	0	Feb 70	(c)				
	St. Paul Island	(b)				June 69	(c)				
Ariz:	Phoenix	14	12	1	5	Oct 69	(c)				
Ark:	Little Rock	7	3	1	2	Aug 69	(c)				
Calif:	Berkeley	18	2	0	1	Nov 69	1	20	1	20	1
	Los Angeles	17	3	0	2	Mar 70	(c)				
C.Z:	Ancon	11	0	0	0	Nov 69	(c)				
Colo:	Denver	18	5	0	2	Nov 69	2	14	(d)		
Conn:	Hartford	18	1	0	0	Sept 69	10	122	10	122	2
Del:	Dover	18	2	0	1	July 69	(c)				
D.C:	Washington	22	0	0	0	Feb 70	(c)				
Fla:	Jacksonville	18	2	0	2	Aug 69	5	101	5	101	43
	Miami	16	2	0	0	Sept 69	6	28	3	19	0
Ga:	Atlanta	17	1	1	1	June 69	2	137	2	137	54
Guam:	Agana	(b)				July 69	(c)				
Hawaii:	Honolulu	25	1	0	0	Jan 70	3	29	(d)		
Idaho:	Boise	18	6	1	3	Jan 70	3	44	3	44	12
Ill:	Springfield	15	4	1	1	Feb 70	(c)				
Ind:	Indianapolis	(b)				June 69	(c)				
Iowa:	Iowa City	15	4	0	1	Nov 69	1	4	1	4	0
Kans:	Topeka	17	4	1	2	Aug 69	1	1	1	1	1
Ky:	Frankfort	13	4	1	2	Feb 70	(c)				
La:	New Orleans	15	1	0	0	Feb 70	4	52	(d)		
Maine:	Augusta	18	1	0	1	Mar 70	13	219	13	219	0
Md:	Baltimore	18	1	0	1	Sept 69	6	43	6	43	5
	Rockville	11	2	0	1	Jan 70	(c)				
Mass:	Lawrence	16	2	0	0	Nov 69	8	183	8	183	8
	Winchester	19	2	0	0	Dec 69	10	235	10	235	0
Mich:	Lansing	18	2	9	1	Jan 70	7	28	7	28	3
Minn:	Minneapolis	16	1	0	1	July 69	2	42	2	42	2
Miss:	Jackson	18	5	0	1	Mar 70	2	45	2	45	6
Mo:	Jefferson City	20	3	0	1	June 69	4	23	4	23	0
Mont:	Helena	19	3	0	1	Dec 69	(c)				
Nebr:	Lincoln	8	7	1	3	June 69	(c)				
Nev:	Las Vegas	13	2	0	1	Sept 69	(c)				
N.H:	Concord	10	2	0	1	Feb 70	1	10	(e)		
N.J:	Trenton	16	1	0	0	Mar 70	6	54	6	54	2
N.Mex:	Santa Fe	9	2	0	1	Dec 69	(c)				
N.Y:	Albany	5	1	0	0	June 69	3	21	3	21	2
	Buffalo	16	1	0	0	Nov 69	(c)				
	New York City	17	1	0	0	Dec 69	(c)				
N.C:	Gastonia	14	8	0	4	Nov 69	3	18	(d)		
N.Dak:	Bismarck	18	7	1	3	Feb 70	(c)				
Ohio:	Cincinnati	(b)				July 69	(c)				
	Columbus	1	1	1	1	Mar 70	1	10	(e)		
	Painesville	20	1	0	1	Sept 69	11	79	11	79	0
Okla:	Oklahoma City	13	4	1	2	Jan 70	(c)				
	Ponca City	20	9	1	3	Sept 69	(c)				
Ore:	Portland	19	1	0	1	June 69	7	107	7	107	6
Pa:	Harrisburg	21	1	0	1	June 69	(c)				
P.R:	San Juan	(b)				Mar 70	(c)				
R.I:	Providence	17	2	0	0	Jan 70	7	133	7	133	19
S.C:	Columbia	16	8	0	3	Dec 69	(c)				
S.Dak:	Pierre	13	16	1	6	Oct 69	(c)				
Tenn:	Nashville	16	3	0	1	Jan 70	4	63	4	63	0
Tex:	Austin	13	6	1	4	July 69	1	7	(d)		
	El Paso	(b)				Feb 70	(c)				
Utah:	Salt Lake City	29	5	0	2	Mar 70	4	19	4	19	5
Vt:	Barre	15	6	0	1	Aug 69	8	131	8	131	48
Va:	Richmond	16	2	0	0	Aug 69	4	77	4	77	14
Wash:	Seattle	3	0	0	0	Aug 69	7	44	(d)		
	Spokane	17	5	1	2	July 69	(c)				
W.Va:	Charleston	8	2	0	1	Dec 69	3	38	3	38	5
Wisc:	Madison	19	2	0	1	Aug 69	5	18	5	18	3
Wyo:	Cheyenne	18	4	0	1	Sept 69	1	415	1	415	0
Network summary		1,050	16	0	1		6	92	5	86	8

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

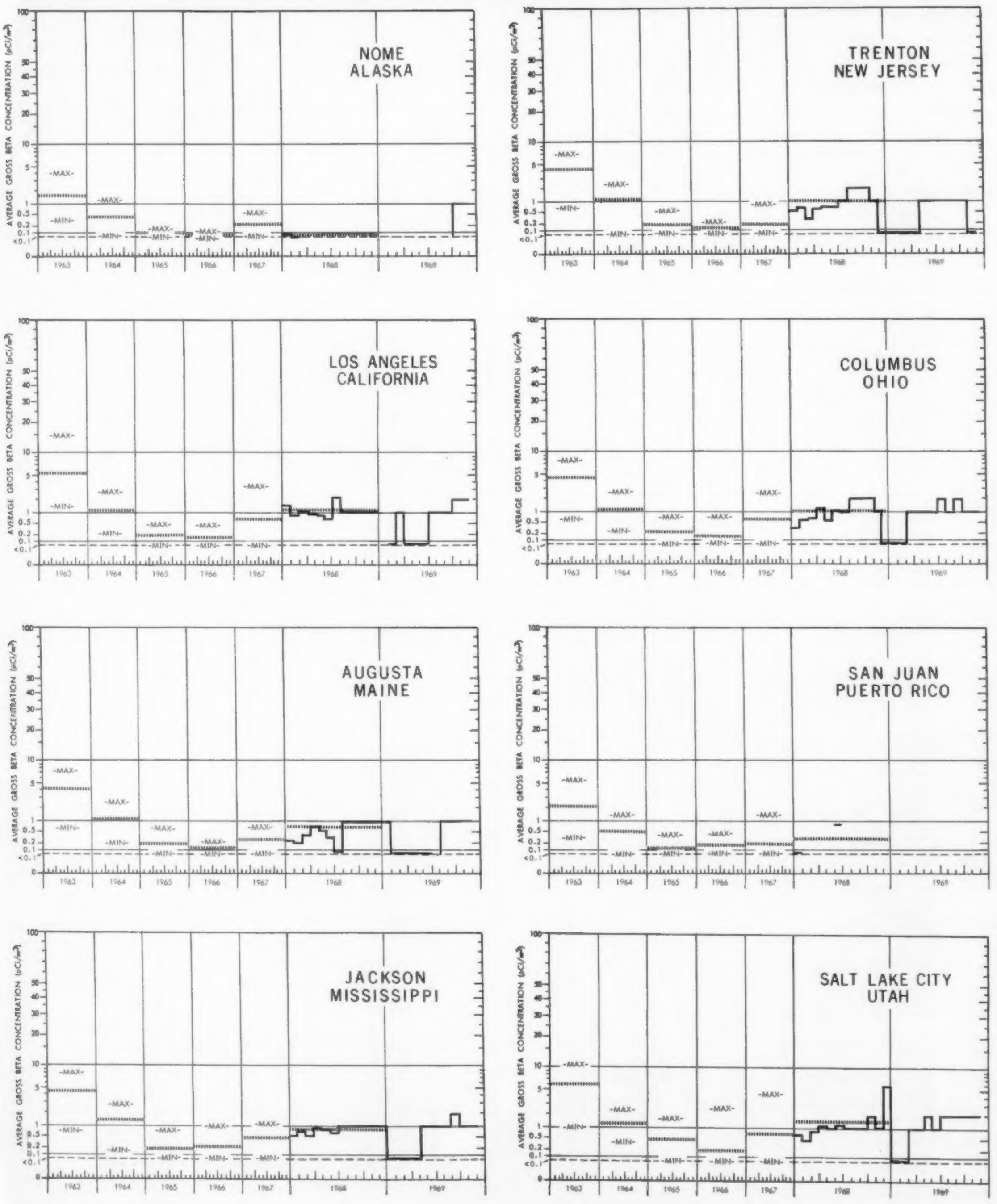

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1963–November 1969

2. Canadian Air and Precipitation Monitoring Program[1], November 1969

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for November 1969 are presented in table 2.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, November 1969

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m^3)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m^2)
Calgary	29	0.1	0.0	0.1	NA	NA
Coral Harbour	26	.1	.0	.1	NA	NA
Edmonton	24	.1	.0	.1	36	0.7
Ft. Churchill	28	.1	.0	.1	23	.9
Ft. William	29	.1	.0	.1	39	1.1
Fredericton	30	.1	.0	.0	13	1.5
Goose Bay	30	.1	.0	.0	22	2.0
Halifax	30	.1	.0	.0	11	1.7
Inuvik	20	.1	.0	.1	103	.7
Montreal	29	.1	.0	.1	8	.9
Moosonee	29	.1	.0	.1	17	.8
Ottawa	29	.1	.0	.1	17	1.7
Quebec	30	.1	.0	.0	15	1.7
Regina	30	.1	.0	.1	147	.4
Resolute	26	.2	.0	.1	48	.2
St. John's, Nfld	28	.1	.0	.1	13	2.2
Saskatoon	28	.1	.0	.1	39	.3
Saulte Ste Marie	28	.1	.0	.1	32	2.3
Toronto	28	.2	.0	.1	33	2.4
Vancouver	30	.1	.0	.0	25	2.3
Whitehorse	30	.1	.0	.0	56	.2
Windsor	30	.2	.0	.1	19	1.5
Winnipeg	30	.2	.1	.1	48	.4
Yellowknife	29	.1	.0	.1	18	.4
Network summary	680	0.2	0.0	0.1	36	1.2

NA, no analysis.

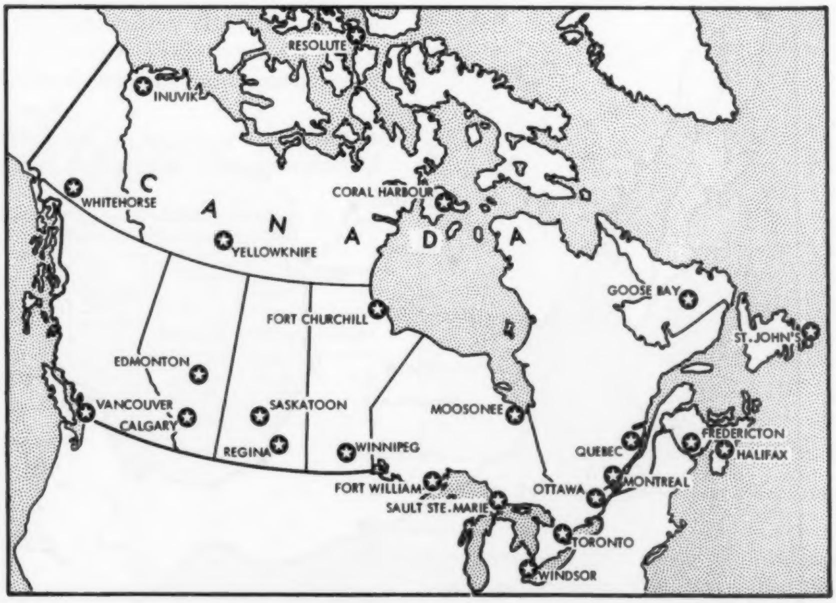

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program July and August 1969

National Commission of Nuclear Energy México, D.F.

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CHEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Prevision del Golfo de Mexico, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency, 6-by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month were needed to get a reliable average radioactivity at each station (*1*).

The maximum, minimum, and average beta radioactivity in surface air during July and August 1969 are presented in tables 3 and 4.

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, July 1969

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	NS			
Chihuahua	15	0.9	0.1	0.4
Ciudad Juárez	6	.8	.2	.5
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	5	.7	.3	.5
Matamoros	NS			
Mazatlán	NS			
Mérida	12	.5	.1	.3
México, D.F.	4	.3	.1	.1
Nuevo Laredo	6	.6	.1	.3
San Luis Potosí	NS			
Tampico	NS			
Torreón	14	1.1	.1	.4
Veracruz	3	.6	.2	.2

NS, no sample, station temporarily shutdown.

Table 4. Mexican gross beta radioactivity of airborne particulates, August 1969

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	NS			
Chihuahua	16	0.4	0.1	0.2
Ciudad Juárez	11	.5	.1	.2
Ensenada	NS			
Guadalajara	NS			
Guaymas	NS			
La Paz	9	2.3	.1	.5
Matamoros	NS			
Mazatlán	NS			
Mérida	15	.2	.1	.1
México, D.F.	4	.1	.1	.1
Nuevo Laredo	NS			
San Luis Potosí	NS			
Tampico	NS			
Torreón	9	.5	.1	.1
Veracruz	7	.2	.1	.1

NS, no sample, station temporarily shutdown.

4. Pan American Air Sampling Program November 1969

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the January 1968 issue of *Radiolgical Health Data and Reports*. The November 1969 air monitoring results from the participating countries are given in table 5.

Figure 5. Pan American Air Sampling Program stations

Table 5. Summary of gross beta radioactivity in Pan American surface air, November 1969

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	13	0.16	0.07	0.11
Bolivia:	La Paz	14	.10	.00	.05
Chile:	Santiago	29	.23	.05	.10
Colombia:	Bogota	19	.08	.00	.02
Ecuador:	Cuenca	NS			
	Guayaquil	3	.06	.02	.04
	Quito	NS			
Guyana:	Georgetown	NS			
Jamaica:	Kingston	17	.12	.01	.03
Peru:	Lima	NS			
Venezuela:	Caracas	19	.03	.00	.01
West Indies:	Trinidad	18	.04	.00	.01
Pan American summary		132	0.23	0.00	0.05

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

NS, no sample.

REFERENCES

(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(6) VASQUEZ, M. and R. M. DE NULMAN. Estudios sobre la radioactividad ambiental en la Republica Méxicana, 1963–1965. Comisión Nacional de Energía Nuclear, Dirección General de Seguridad Radiologica (1966).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Offsite Surveillance Around the Nevada Test Site,[1] July-December 1965

Southwestern Radiological Health Laboratory, DHEW, and *Nevada Operations Office, AEC*

Under a Memorandum of Understanding between the U.S. Atomic Energy Commission (AEC), and the Public Health Service, the Southwestern Radiological Health Laboratory (SWRHL) of the Bureau of Radiological Health performed radiological surveillance in the offsite area surrounding the Nevada Test Site (NTS) during the period from July through December 1965. During this period, nine announced underground nuclear tests were conducted at the NTS and one was conducted on Amchitka Island in the Aleutian Chain.

[1] Summarized from Report No. SWRHL–24r (*1*).

This latter underground test was part of the Vela Uniform program and offsite coverage was provided by the SWRHL.

Operational procedures, NTS

Both ground and aerial monitoring capabilities were maintained throughout the period. Mobile ground monitoring teams were positioned in offsite areas prior to each event and an aerial monitoring team was prepared to track any radioactive releases to determine relative radiation intensities and to indicate cloud position, speed, and direction. Monitoring teams were equipped with

Figure 1. Air surveillance network stations other than Nevada

Figure 2. Air surveillance network stations in Nevada

Eberline E-500B, Precision Model 111 Standard "Scintillator," Beckman MX–5, and Tracerlab AN/PDR TIB survey instruments. Eberline RM–11 gamma rate recorders were also utilized to document cloud passage at fixed ground locations. During this period, the SWRHL Air Surveillance Network (ASN) operated 98 stations in every State west of the Mississippi except Montana and North Dakota (figures 1 and 2). The ASN air sampler used was a Gelman "Tempest" equipped to use a 4-inch diameter Whatman 541 filter paper and an MSA[2] charcoal cartridge.

The established milk sampling program from both commercial dairies and private producers continued throughout the 6-month period. A total of 204 milk samples were collected from 59 sources. Water samples were also collected routinely from both potable and nonpotable supplies. A total of 218 water samples from 63 different locations was collected primarily on a monthly basis. Vegetation samples, the results of which are used to delineate any fallout pattern, are collected only after a known release of radioactivity; none were collected during this period.

Approximately 150 residents in the offsite area wore film badge dosimeters throughout this period. Seventy-five permanent area film badge stations were also used. The dosimeter used contained DuPont type 555 film. Dose, as determined from this film, is accurate to ±50 percent in the 20 to 100 mR range and ±10 percent in the 100 to 2,000 mR range.

A PHS medical officer was available for any cases of a medical nature which might have occurred as a result of the nuclear tests. Similarly, an Army veterinarian and a PHS veterinarian were available to conduct wildlife or domestic livestock investigations. A number of offsite residents participated in the program by operating all routine air sampling stations except those in Las Vegas, and as stated above, by wearing film badge dosimeters.

[2] Mine Safety Appliance Co.

Operational procedures—Amchitka Island

On the day of the event (October 29, 1965) named Project Longshot, nine monitors were standing by on three other islands in the Aleutian Chain and on the Alaskan Mainland. Additionally, one PHS staff member was at the Amchitka control point and three PHS personnel were airborne in a USAF C–54 aircraft in the Amchitka area. A PHS medical officer was stationed on a U.S. Coast Guard cutter which was patrolling in the vicinity of Amchitka Island.

Each monitor was equipped with an Eberline E–500B survey instrument and a Victoreen Radector Model AGB–50B–SR.

Nineteen air sampling stations were established during October in the Aleutian Islands and at other Alaskan locations. These Alaskan stations operated through October and in some cases, into November (figure 3).

On the day of the event, 16 thermoluminescent dosimeters and 25 film badges were placed at stations or were worn by ten PHS personnel.

No milk, water, or vegetation samples were collected specifically for this event.

Analytical procedures

Samples were returned to the SWRHL in Las Vegas for radiological analysis. Air sample particulate filters from the NTS and Amchitka Island networks were beta counted in a Beckman wide-beta, low-background, proportional counter system. Selected filters, all charcoal cartridges, and water and milk samples were analyzed for gamma-ray-emitting radionuclides using a 4- by 4-inch NaI(Tl) crystal coupled to a TMC Model 404C gamma pulse-height analyzer. The lower limit of detection for gamma-ray emitters in milk samples was 20 pCi/liter at the time of count. Gamma-ray spectra were evaluated using a matrix technique which allowed for the simultaneous determination of eight nuclides.

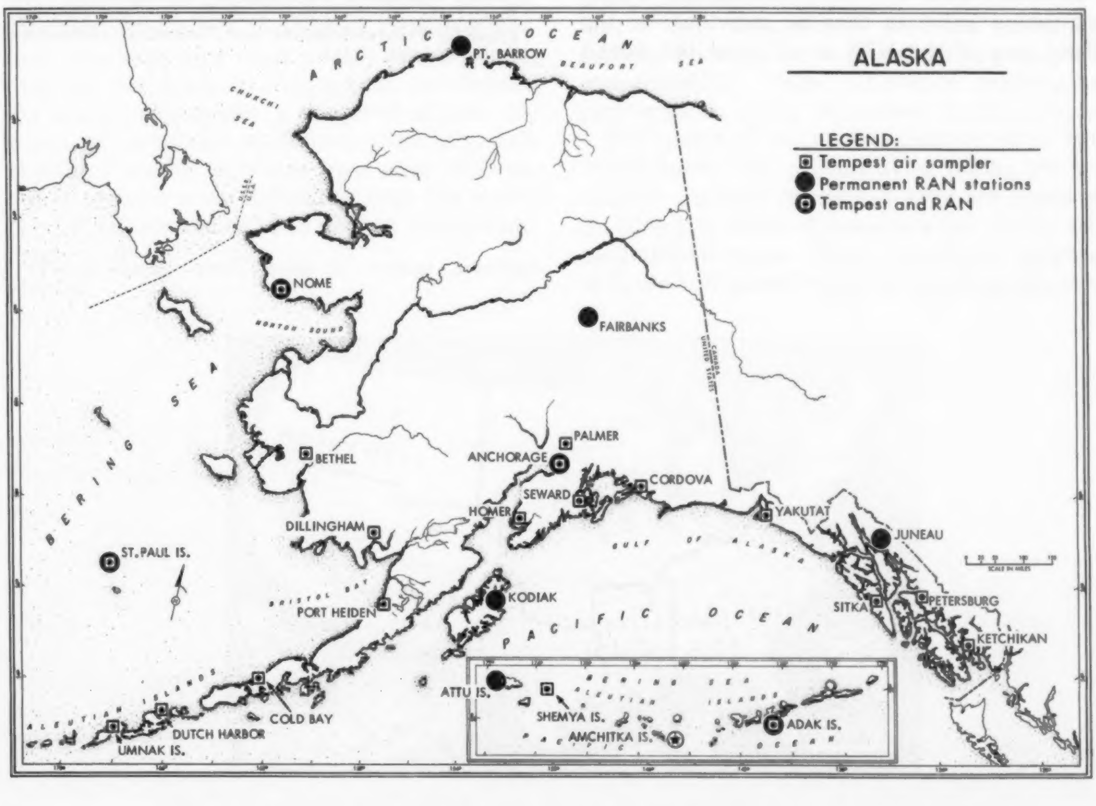

Figure 3. Air sampling stations in the Aleutian Islands and other Alaskan locations

Results

No radioactive effluent was detected in offsite populated areas as a result of any nuclear test conducted during this period at NTS or in Alaska. A few milk samples collected north of the NTS in early July contained iodine–131; however, the activity in these samples is attributed to the Phoebus 1A reactor experiment which was conducted at the Nuclear Rocket Development Station (NRDS) on June 25, 1965. The results of this Phoebus experiment were published in SWRHL–19r (*2*) and SWRHL–23r (*3*). Two milk samples collected in September and one collected in October also contained iodine–131; the values, however, were at or near the detection limit for this nuclide (20 pCi/liter) and cannot be attributed to any nuclear test release, foreign or domestic.

Conclusions

Environmental radiation surveillance during this period indicates that no individual in the offsite area of the NTS or of Amchitka Island received an exposure, as a result of nuclear test activities, which exceeded the guides established by the AEC or recommended by the Federal Radiation Council.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE, SOUTHWESTERN RADIOLOGICAL HEALTH LABORATORY. Offsite Surveillance Activities of the Southwestern Radiological Health Laboratory from July through December 1965, Report No. SWRHL–24r. Available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151 (May 23, 1966).

(*2*) PUBLIC HEALTH SERVICE, SOUTHWESTERN RADIOLOGICAL HEALTH LABORATORY. Final Report of Offsite Surveillance for the Phoebus 1A Experiment, Report No. SWRHL–19r. Available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151.

(*3*) PUBLIC HEALTH SERVICE, SOUTHWESTERN RADIOLOGICAL HEALTH LABORATORY. Offsite Surveillance Activities of the Southwestern Radiological Health Laboratory from January through June 1965, Report No. SWRHL–23r. Available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151.

Strontium-90 in Human Bone,[1] January-March 1969

Bureau of Radiological Health
U.S. Public Health Service

To obtain data on the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older-age groups have shown their bone strontium–90 content to be low and age-independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

[1] Period during which death or surgical procedure occurred.

Laboratory procedures

The bones are analyzed at Northeastern Radiological Health Laboratory of the Bureau of Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium–90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium–90 content is then calculated (*3*) from the yttrium–90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples.

The analytical results for strontium–90 in individual bones from persons dying during the first quarter (January–March) of 1969 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries

Figure 1. Geographical regions for human bone sampling

Table 1. Strontium-90 in human bone, January–March 1969

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Northeast:						
Massachusetts	V	00	M	55.6 ± 6.9	36.4	1.52
New York	V	1	M	40.6 ± 6.0	23.8	1.70
Massachusetts	V	2	M	153.0 ± 13.0	32.7	4.67
Vermont	V	2	M	155.0 ± 13.0	31.0	5.00
New York	V	2	F	84.9 ± 7.9	23.3	3.64
	V	2	M	79.8 ± 8.8	33.9	2.35
	V	2	F	53.1 ± 6.2	19.6	2.70
Massachusetts	V	2	M	145.0 ± 12.0	38.7	3.74
New York	V	2	M	66.3 ± 7.3	29.2	2.27
	V	3	F	53.5 ± 6.8	21.9	2.44
Massachusetts	V	5	F	187.0 ± 11.0	33.2	5.63
	V	6	M	113.0 ± 13.0	27.6	4.09
New York	V	6	F	104.0 ± 9.5	43.5	2.39
	V	7	M	31.9 ± 7.2	23.7	1.34
Vermont	V	8	M	61.3 ± 9.3	30.4	2.01
Massachusetts	V	9	F	109.0 ± 8.9	30.4	3.58
New York	V	9	M	58.6 ± 7.4	31.0	1.89
	V	10	M	77.1 ± 7.4	39.2	1.96
Massachusetts	V	11	M	113.0 ± 11.0	47.6	2.37
	V	13	F	70.6 ± 5.6	29.5	2.39
	V	13	M	108.0 ± 11.0	32.7	3.30
New York	V	15	F	85.1 ± 7.3	37.9	2.24
	V	15	M	44.5 ± 6.2	40.9	1.08
Rhode Island	V	16	M	121.0 ± 9.4	44.8	2.70
New York	V	16	M	105.0 ± 8.8	38.7	2.71
Massachusetts	V	18	M	150.0 ± 13.0	47.0	3.19
	V, R	19	M	55.4 ± 7.3	31.9	1.73
Rhode Island	V, S	19	M	70.4 ± 6.9	30.3	2.32
Massachusetts	V	19	M	120.0 ± 11.0	37.0	3.24
New York	V	22	F	113.0 ± 8.8	50.4	2.24
Southeast:						
Maryland	V	0	M	68.2 ± 8.2	41.3	1.65
	V	0	M	80.0 ± 10.0	39.7	2.01
Delaware	V	8	M	50.8 ± 6.8	31.8	1.59
South Carolina	V	11	F	141.0 ± 11.0	37.3	3.78
Maryland	V	11	F	132.0 ± 10.0	43.1	3.06
	V	11	M	81.3 ± 9.5	37.7	2.15
	V	14	F	105.0 ± 10.0	53.4	1.96
	V	14	M	89.8 ± 9.9	39.4	2.27
	V	16	M	130.0 ± 14.0	46.5	2.79
	V	17	M	111.0 ± 11.0	51.3	2.16
	V	17	M	96.3 ± 10.0	52.8	1.82
	V	17	M	106.0 ± 42.0	56.3	1.88
	V	18	M	132.0 ± 11.0	48.6	2.71
	V	18	M	103.0 ± 10.0	47.9	2.15
	V	18	M	180.0 ± 12.0	50.1	3.59
	V	19	M	71.9 ± 11.0	46.4	1.54
	V	21	F	92.3 ± 9.5	51.1	1.80
Central:						
Ohio	V	0	M	85.7 ± 12.0	31.4	2.72
Minnesota	V	3	F	103.0 ± 18.0	45.4	2.26
Ohio	V	5	M	89.0 ± 12.0	56.2	1.58
Michigan	V	5	F	60.6 ± 7.1	32.8	1.84
Ohio	V	7	M	37.5 ± 7.2	26.1	1.43
Wisconsin	V	8	F	54.8 ± 6.2	34.1	1.60
Ohio	V	8	M	110.0 ± 10.0	35.8	3.07
Michigan	V	9	M	83.1 ± 8.4	38.3	2.16
Ohio	V	9	M	80.8 ± 7.6	31.9	2.53
Michigan	V	10	M	95.2 ± 9.0	42.4	2.24
Wisconsin	V	10	F	54.4 ± 5.9	35.2	1.54
	V	10	M	70.3 ± 8.0	40.4	1.74
Ohio	V	12	M	81.3 ± 8.4	46.7	1.74
	V	12	M	98.7 ± 9.0	47.0	2.10
Iowa	V	12	M	88.6 ± 6.7	37.7	2.35
Ohio	V	13	F	142.0 ± 12.0	53.3	2.66
	V	14	M	73.5 ± 8.0	38.2	1.92
	V	14	M	91.2 ± 10.0	61.0	1.49
Iowa	V	14	M	50.2 ± 6.7	41.7	1.20
Ohio	V	14	M	76.5 ± 8.0	41.3	1.85
	V	15	F	121.0 ± 12.0	48.5	2.49
	V	16	F	104.0 ± 9.7	52.6	1.97
Michigan	V	17	M	71.8 ± 9.6	35.7	2.01
	V	17	M	208.0 ± 16.0	61.9	3.36
Ohio	V	18	M	97.0 ± 10.0	52.4	1.85
	V	18	F	104.0 ± 13.0	54.8	1.89
	V	18	M	115.0 ± 12.0	56.1	2.04
	V	19	F	124.0 ± 11.0	56.3	2.20
	V	19	F	177.0 ± 11.0	43.7	4.05
Minnesota	V	21	F	47.0 ± 8.1	31.5	1.49
Ohio	V	22	M	78.9 ± 9.3	50.8	1.55
	V	22	M	90.8 ± 11.0	52.4	1.73
	V	23	F	78.4 ± 8.6	55.7	1.40
	V	23	F	87.2 ± 9.6	55.5	1.57
	V	24	F	84.7 ± 7.5	53.8	1.57
	V	25	M	90.4 ± 9.8	54.5	1.65

See footnotes at end of table.

Table 1. Strontium-90 in human bone, January-March 1969—Continued

Bone region and State	Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Northwest:						
Oregon	V	1	M	77.6 ± 9.0	31.3	2.47
	V	14	F	83.7 ± 12.0	56.4	1.48
Washington	V	17	M	91.0 ± 9.9	40.2	2.26
Oregon	V	18	M	85.5 ± 8.8	44.4	1.92
	V	19	M	106.0 ± 13.0	55.9	1.89
	V	19	F	129.0 ± 13.0	67.9	1.89
	V	20	M	62.4 ± 8.9	45.9	1.35
Washington	T	22	M	222.0 ± 15.0	207.0	1.07
Oregon	V	23	M	83.1 ± 9.7	54.9	1.51
Southwest:						
Colorado	V	6	M	83.5 ± 7.7	27.1	3.08
Utah	F	17	F	248.0 ± 15.0	152.0	1.63
Colorado	V	18	M	63.3 ± 7.9	44.6	1.41
	V	18	M	36.7 ± 7.9	47.3	.77
Utah	V	18	F	105.0 ± 11.0	55.8	1.88
Colorado	V	19	M	81.4 ± 8.4	55.9	1.45
	V	21	M	75.3 ± 7.5	50.4	1.49
	V	21	M	88.9 ± 12.0	52.7	1.68
Texas	V	21	M	66.7 ± 7.8	53.3	1.25
North:						
Alaska	R	15	F	314.0 ± 40.0	127.0	2.47
	V	25	M	76.0 ± 10.0	46.1	1.64

[a] Type of bone, V, vertebrae; R, rib; S, sternum; T, tibia; F, femur.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2*–*5*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1968	September 1969
October–December 1968	December 1969

REFERENCES

(*1*) RIVERA, J. Strontium-90 in human vertebrae, 1962–1963. Radiol Health Data 5:511–513 (October 1964).

(*2*) WEISS, E. S., W. H. LAND, K. H. FALTER, and R. M. HALLISEY. Strontium-90 content of human bones, 1961–1963. Radiol Health Data 5:231–239 (May 1964).

(*3*) PUBLIC HEALTH SERVICE, NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Analysis of environmental samples, chemical and radiochemical procedures, NERHL 64-1. Northeastern Radiological Health Laboratory, Winchester, Mass. (April 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium-90 in human bone, 1962–1963. Radiol Health Data 5:620–628 (December 1964).

(*5*) HALLISEY, R. M., and M. A. WALL. Stiontium-90 in human bone, 1964–1965. Radiol Health Data Rep 8:415–419 (August 1967).

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Atomics International and Feed Materials Production Center.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International[2] January–June 1969

North American Rockwell Corporation
Canoga Park, Calif.

Atomics International, a division of North American Rockwell Corporation, has been engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants for medical, industrial, and scientific applications.

The company headquarters is located in Canoga Park, California, approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is in Ventura County in the Simi Hills approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

The basic concept of radiological hazard control at Atomics International encourages total containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a check on the effectiveness of radiological safety procedures and of engineering safeguards incorporated into facility design.

The environs of Atomic International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. In addition, continuous environmental air monitoring at the sites provides information concerning airborne particulate radioactivity.

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV–70 filter paper which is automatically changed at the end of each sampling period. The filter is removed from the sampler and counted after the radioactivity is allowed to decay for at least 72 hours. The volume of a typical daily environmental air sample is approximately 20-cubic meters. The average concentration of long-lived beta-gamma radioactivity on airborne particulates is presented in table 1 for January–June 1969.

[2] Summarized from "Environmental Monitoring, Semiannual Report, January 1, 1969 to June 30, 1969" Atomics International, Division of North American Rockwell Corporation.

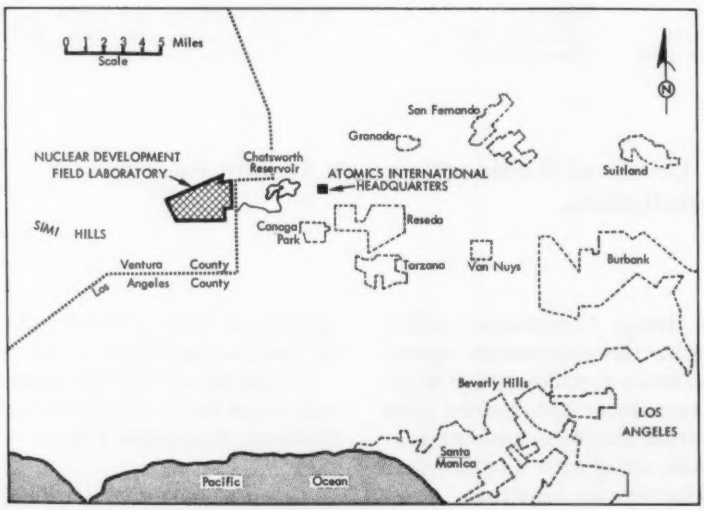

Figure 1. Atomics International facilities and vicinity

Table 1. Beta-gamma radioactivity of airborne particulates, Atomics, January–June 1969

Location	Number of samples	Average concentration (pCi/m³)
Headquarters	362	0.25
NDFL	1,214	.24

When abnormally high airborne radioactivities are observed, the radioactivity decay data are plotted to determine the presence of short-lived isotopes other than naturally occurring radon, thoron, and daughters. If fall-out is suspected, the decay characteristics are observed. If the radioactivity decays as a function of $t^{-1.2}$, the data curve is extrapolated in order to determine the date of origin. This data is compared with the dates of publicized nuclear detonations to determine if the abnormal airborne radioactivity was caused by such detonations.

A graph of averaged long-lived airborne radioactivity concentrations detected at the headquarters and NDFL facilities during the first half of 1969 is presented in figure 2. The graph shows the incidence of five major peaks of extended duration during the reporting period, with a generally increasing trend through the spring months following a period of airborne radioactivity suppression by heavy rainfall during January and February.

Water monitoring

Process water used at the NDFL is obtained from Ventura County Water District No. 10 and distributed onsite by the same piping system previously used when process water was supplied by onsite wells. Pressure is provided by elevated storage tanks, one 50,000-gallon and one 500,000-gallon tank onsite. While clinically potable, the water is not used for drinking. Bottled potable water is delivered by a vendor and is not analyzed. Water from the pipe system is sampled monthly at two locations. The average process water radioactivity concentration is presented in table 2.

Table 2. Process water radioactivity, NDFL site January–June 1969

Type of radioactivity	Number of samples	Average concentration (pCi/liter)
Alpha	12	0.16
Beta-gamma	12	4.4

Soil, vegetation, and water are sampled monthly at Chatsworth Reservoir which is operated by the Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The average radioactivity for both surface and supply water samples is presented in table 3.

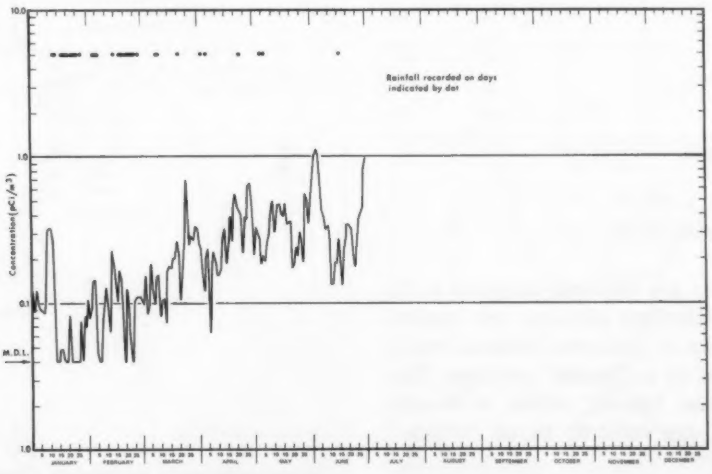

Figure 2. Long-lived airborne radioactivity at Atomics International, January–June 1969

Table 3. Chatsworth Reservoir water radioactivity Atomics, January–June 1969

Sample	Type of radioactivity	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	6	0.35
	Beta-gamma	6	6.1
Supply inlet	Alpha	6	.15
	Beta-gamma	6	6.0

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66–49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 3.4 miles downstream from the south NDFL boundary. Samples, obtained and analyzed monthly, include stream bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 4.

Table 4. Radioactivity in the Rocketdyne reservoir and Bell Creek[a], January–June 1969

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir station 6, water[a] (pCi/liter)	6	0.12	4.9
Reservoir station 12, water[a] (pCi/liter)	5	.15	4.5
Bell Creek mud (pCi/g)	6	.42	30
Bell Creek vegetation (pCi/g ash)	6	.41	184
Bell Creek water (pCi/liter)	6	.04	4.1

[a] Location not shown on figure 1.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 24 locations. Twelve sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 12 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Surface soil types available for sampling range from decomposed granite to clay and loam. Samples are taken from the top half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 5.

Table 5. Radioactivity in the soil, Atomics, January–June 1969

Area	Type of radioactivity	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	72	0.43
	Beta-gamma	72	27
Offsite	Alpha	24	.46
	Beta-gamma	24	26

Vegetation samples obtained in the field are of the same plant type wherever possible, generally sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 6.

Table 6. Radioactivity in vegetation, Atomics, January–June 1969

Area	Type of radioactivity	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	72	0.45
	Beta-gamma	72	160
Offsite	Alpha	24	.38
	Beta-gamma	24	142

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1968	December 1968
July–December 1968	July 1969

2. Feed Materials Production Center[3] January–June 1969

National Lead Company
Fernald, Ohio

The Feed Materials Production Center (FMPC) is operated by the National Lead Company of Ohio for the AEC. The location as related to populated areas is shown in figure 3. Cincinnati and Hamilton, the larger nearby communities, are situated 20 and 10 miles from the center, respectively. Operations at this project deal with the processing of high-grade uranium ores and ore concentrates to produce metallic uranium and with fabricating the metal into fuel elements.

During the past 2 years, the project has also processed thorium to produce purified oxide and metal. The process and use of these products is essentially the same as used in producing uranium. Because of the small amounts of thorium processed by the project, environmental analyses for thorium are not considered necessary.

During the many involved reactions and processes that lead to the production of reactor fuels, various liquid and airborne wastes are generated. These wastes contain varying quantities of uranium and thorium. Various in-plant methods are used to curtail their release into the environment surrounding the plant. Almost complete removal of the materials is accomplished by using dust collectors and waste treatment processes. In order to determine what concentrations reach the area surrounding the project, an environmental survey program has been established which consists of water and air sampling of the environs and performing those analyses on the samples that are indicative of material released from the plants.

Air monitoring

Onsite air samples are obtained from four permanent perimeter air sampling stations, located at the four corners of the production area as shown in figure 4. Samples from these perimeter stations are collected once each week and analyzed for uranium and total radioactivity. Offsite samples are collected by a mobile air sampling unit. The location at which samples are collected is determined by local meteorological conditions on the day of sampling. Approximately 20 percent of all samples are taken upwind of the FMPC plant.

[3] Summarized from "Feed Materials Production Center Environmental Monitoring Semiannual Report for the First Half of 1969, Summary Report for 1968" (NLC)–1046.

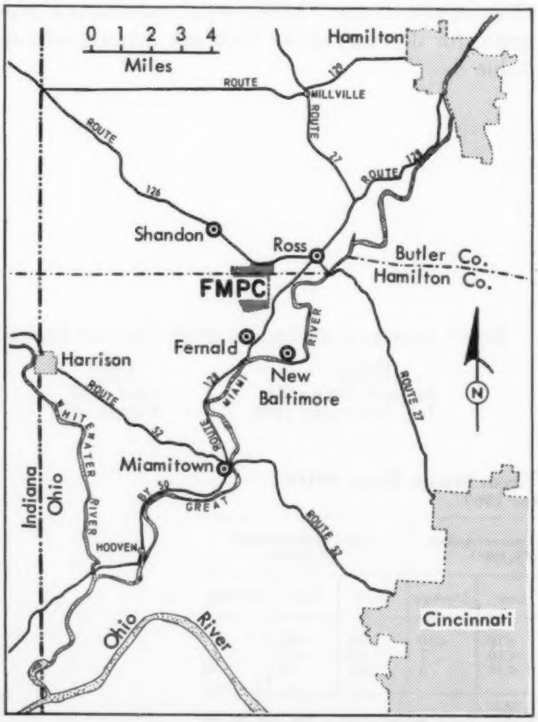

Figure 3. Area map of Feed Materials Production Center

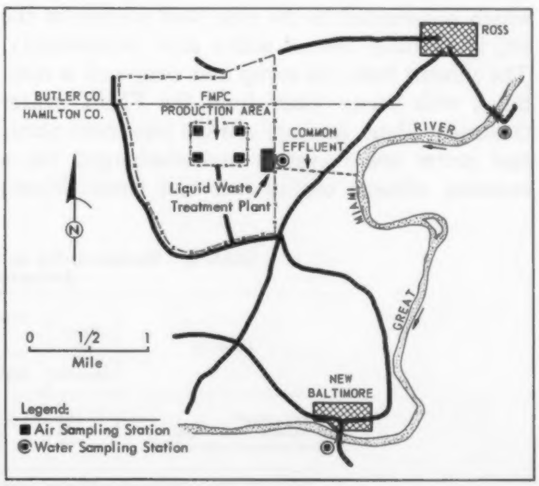

Figure 4. Air and water sampling stations, FMPC

Table 7. Radioactivity levels of airborne particulates, FMPC, January–June 1969

Location	Number of samples	Uranium concentration[a] (pCi/m³) Maximum	Minimum	Average	Total radioactivity[b] (pCi/m³) Maximum	Minimum	Average
Onsite:							
Southwest	25	1.0	<0.1	0.3	1.8	<0.1	0.5
Northwest	25	.2	< .1	.1	.5	< .1	.2
Northeast	25	.3	< .1	.1	.8	< .1	.3
Southeast	25	.3	< .1	.1	.6	< .1	.3
All onsite samples	100			.2			.3
Offsite:							
0–2 miles from FMPC	34	2.3	< .1	.4	8.0	< .1	1.1
2–4 miles from FMPC	36	.2	< .1	.1	.7	< .1	.2
4–8 miles from FMPC	30	.3	< .1	.1	.7	< .1	.3
8–12 miles from FMPC	14	.1	< .1	.1	.4	< .1	.2
All offsite samples	114			.2			.5

[a] AEC radiation protection standard—2 pCi/m³

[b] AEC radiation protection standard—100 pCi/m³. Total radioactivity is the sum of the alpha and beta radioactivity.

Replicate samples are taken at each sampling point and averaged to obtain a representative concentration for that location. Concentrations of uranium and total radioactivity of airborne particulates sampled at onsite and offsite locations are given in table 7.

Water monitoring

Each of the individual production plants on the project has collection sumps and treatment equipment to remove the uranium from the process waste water. The effluent from the plants is collected at a general sump for equalization and settling. The clear water from the sump is pumped to the river. The solid portion is pumped to a chemical waste pit for further settling. The flow, which is decanted to the clear well portion of the pit, is virtually free of solids and radioactivity. The effluent from the sump and clear well is combined with waste water from the FMPC water treatment plant, sanitary sewage treatment plant, and storm sewer system and discharged via a common effluent outfall into the Great Miami River. A Parshal-Flume-type water sampler collects samples of the combined effluent stream, which are removed and analyzed daily. These results are utilized with measurements of river flow in calculating the radioactive contaminant concentrations added to the river. Weekly spot samples are obtained upstream; downstream, a continuous sample is taken for a 24-hour period and random samples are analyzed each week. The results of the FMPC water monitoring program for January–June 1969 are summarized in table 8.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1968	April 1969
July–December 1968	August 1969

Table 8. Radioactivity in the Great Miami River, FMPC, January–June 1969

Location	Number of samples	Uranium concentration[a] (pCi/liter) High	Low	Average	Total radioactivity[b] (pCi/liter) High	Low	Average
Sewer outfall	181	<10	<10	<10	80	<10	10
Upstream from outfall	23	30	<10	7	60	<10	20
Downstream from outfall	25	20	<10	3	120	10	20

[a] AEC radiation protection standard—20,000 pCi/liter.

[b] AEC radiation protection standard—3,000 pCi/liter. Total radioactivity is the sum of the alpha and beta radioactivity.

Reported Nuclear Detonations, February 1970

(Includes seismic signals foreign test areas)

The U.S. Atomic Energy Commission announced that five nuclear tests were conducted by the Atomic Energy Commission at its Nevada Test Site during February 1970.

Two nuclear tests of the low-intermediate range (20–200 kilotons TNT equivalent) were conducted underground on February 4 and 5, 1970, by the Atomic Energy Commission at its Nevada Test Site.

A nuclear test of low yield (less than 20 kilotons TNT equivalent) was announced by the AEC as having been conducted underground on February 11, 1970, at its Nevada Test Site.

Two other underground nuclear tests of low-intermediate yield range (20–200 kilotons TNT equivalent) were conducted February 25 and 26, 1970, by the Atomic Energy Commission at its Nevada Test Site.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

RESULTS OF A PROGRAM DIRECTED TOWARD REDUCTION OF DENTAL X-RAY EXPOSURE. *Robert B. Rosenthal and James C. Malcolm. Radiological Health Data and Reports, Vol. 11, March 1970,* pp. 109–155.

X-ray safety surveys in 208 dental offices revealed that almost one million radiographic films were exposed annually. A special study was made of procedural factors affecting roentgen exposure at the cone tip of dental x-ray machines; these were film speed, developing technique, and kilovoltage. Although only 27 percent of the offices were using slow or intermediate speed film, they were found to be responsible for 45 percent of the total cone-tip exposure. A change to faster film reduced their exposure levels by 54 percent. Offices accepting recommended changes in developing technique reduced their exposure levels by 43 percent. The program's effect was an overall exposure reduction of 27 percent. With properly developed fast film, the median exposure levels ranged from 0.19 R/film at 90–100 kVp to 0.62 R/film at 45–55 kVp. The accuracy of electric and electronic timers was evaluated in selected offices.
KEYWORDS: California, dental, film, surveys, timers, x-ray, x-ray machines.

SURVEY RESULTS OF THE USE OF X RAYS IN THE HEALING ARTS SPECIALTIES IN NORTH DAKOTA, 1964–1968. *James A. Kraeger and Gene A. Christianson. Radiological Health Data and Reports, Vol. 11, March 1970,* pp. 117–128.

The x-ray facilities of all healing arts specialties (except dentistry) in North Dakota were surveyed by the State Department of Health to determine the degree of compliance of the x-ray facilities with the recommendations published in NBS Handbook 76. An average of 8,529 patients is radiographed per week in the helaing arts specialties in North Dakota, for a total of 443,508 patients radiographed per year. Hospitals and multiple-specialty clinics account for 81 percent of the radiographs. An average of 881 patients receives a fluoroscopic examination each week for a total of 45,812 examinations per year. Of this fluoroscopic workload, 88 percent are conducted in hospitals and multiple-specialty clinics. Fifty-eight percent of the diagnostic x-ray machines were found to be deficient upon initial evaluation. The majority of the deficiencies were inadequate collimation and/or inadequate filtration of the useful x-ray beam. Major deficiencies resulting in an unnecessary genetically significant dose were found to exist in facilities that exposure 195,676 persons annually. Forty-nine percent of the individuals operating x-ray equipment in North Dakota are not registered with The American Registry of Radiologic Technologists. Of the non-registered technicians, 76 percent had less than a year of x-ray training and 74 percent indicated that aspects of x-ray protection were not included in their training.
KEYWORDS: Healing arts specialties, North Dakota, survey, X-ray facilities.

STRONTIUM AND PLUTONIUM ISOTOPES IN GROUND LEVEL AIR, OCTOBER 1963–MARCH 1969. *B. Shleien, J. A. Cochran, and P. J. Magno. Radiological Health Data and Reports, Vol. 11, March 1970,* pp. 129–134.

Data are presented on monthly concentrations of strontium–90, strontium–89, plutonium–239, and plutonium–238 in ground level airborne particulates collected at Winchester, Mass., from October 1963 (for radionuclides of strontium) and May 1965 (for radionuclides of plutonium) to March 1969. The ratio of strontium–89 to strontium–90 in these samples indicates an influx of strontium–90 following all but the sixth atmospheric detonation on the Chinese mainland. It is estimated that in 1968 approximately 60 percent of the strontium–90 present in ground level air was of post-1963 origin. The ratio of plutonium–239 to strontium–90 prior to February 1968 was 0.017 ± 0.009. There was a gradual increase in this ratio later in 1968 which is attributed to debris following the sixth, seventh, and eighth tests on the Chinese mainland. Levels of plutonium–238 in SNAP–9A debris in ground level air are somewhat lower than had been predicted.
KEYWORDS: Airborne particulates, Massachusetts, plutonium–238, plutonium–239, strontium–89, strontium–90.

ORDER BLANK FOR RHD&R

To: Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

Please enter my subscription for Radiological Health Data and Reports. I am enclosing Money Order ☐ Check☐ for this subscription. ($6.00 a year; $1.50 additional for foreign mailing.)

Please address RHD&R as follows.______________________________

____

____

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C., 1969
For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Subscription price $6.00 a year, $1.50 additional for foreign mailing.
Price for a single copy of this issue is 50 cents.

GUIDE FOR AUTHORS

The editorial staff invites reports and technical notes containing information related to radiological health. Proposed reports and notes should contain data and interpretations. All accepted manuscripts are subject to copy editing with approval of the author. The author is responsible for all statements made in his work.

Manuscripts are received with the understanding that other identical manuscripts are not under simultaneous consideration nor have appeared in any other publication.

The mission of *Radiological Health Data and Reports* is stated on the title page. It is suggested that authors read it for orientation of subject matter.

Submission of manuscripts

Send original and one legible copy of the paper, typed double-spaced on 8½ by 11-inch white bond with 1-inch margins.

Submitted manuscripts should be sent to Managing Editor, Radiological Health Data and Reports, Bureau of Radiological Health, PHS, Rockville, Md. 20852.

Preparation of manuscripts

The Government Printing Office style manual is used as a general guide in the preparation of all copy for *Radiological Health Data and Reports*. In addition, *Radiological Health Data and Reports* has developed a "Guide" regarding manuscript preparation which is available upon request. However, for most instances, past issues of *Radiological Health Data and Reports* would serve as a suitable guide in preparing manuscripts.

Titles, authors: Titles should be concise and informative enough to facilitate indexing. Names of authors should appear on the third line below the manuscript title. Affiliation of each author should be given by a brief footnote including titles, professional connections at the time of writing, present affiliation if different, and present address.

Abstracts: Manuscripts should include a 100- to 150-word abstract which is a factual (not descriptive) summary of the work. It should clearly and concisely state the purpose of the investigation, methods, results and conclusions. Findings that can be stated clearly and simply should be given rather than to state that results were obtained.

A list of suggested keywords (descriptors) which are appropriate indexing terms should be given following the abstract.

Introductory paragraph: The purpose of the investigation should be stated as early as possible in the introductory paragraph.

Methods: For analytical, statistical, and theoretical methods that have appeared in published literature a general description with references to sources is sufficient. New methods should be described clearly and concisely with emphasis on new features. Both old and new methods, materials, and equipment, should be described clearly enough so that limitations of measurements and calculations will be clear to the readers. Errors associated with analytical measurements and related calculations should be given either as general estimates in the text or for specific data in appropriate tables or graphs whenever possible.

Illustrations: Glossy photographic prints or original illustrations suitable for reproduction which help enhance the understanding of the text should be included with the manuscript. Graphic materials should be of sufficient size so that lettering will be legible after reduction to printed page size (8½ by 6½ inches).

All illustrations should be numbered and each legend should be typed double-spaced on a separate sheet of paper. Legends should be brief and understandable without reference to text. The following information should be typed on a gummed label or adhesive strip and affixed to the back of each illustration: figure number, legend, and title of manuscript or name of senior author.

Tables: Tables should be self-explanatory and should supplement, not duplicate, the text. Each table should be typed on a separate sheet, double-spaced. All tables must be numbered consecutively beginning with 1, and each must have a title.

Equations: All equations must be typewritten, preferably containing symbols which are defined immediately below the equation. The definition of symbols should include the units of each term. Special symbols, such as Greek letters, may be printed carefully in the proper size, and exponents and subscripts should be clearly positioned. Mathematical notations should be simple, avoiding when feasible such complexities as fractions with fractions, subscripts with subscripts, etc.

Symbols and units: The use of internationally accepted units of measurements is preferred. A brief list of symbols and units commonly used in *Radiological Health Data and Reports* is given on the inside front cover of every issue and examples of most other matters of preferred usage may be found by examining recent issues. Isotope mass numbers are placed at the upper left of elements in long series or formulas, *e.g.*, ^{137}Cs; however, elements are spelled out in text and tables, with isotopes of the elements having a hyphen between element name and mass number; *e.g.*, strontium-90.

References: References should be typed on a separate sheet of paper.

Personal communications and unpublished data should not be included in the list of references. The following minimum data for each reference should be typed double-spaced: names of all authors in caps, complete title of article cited, name of journal abbreviated according to *Index Medicus*, volume number, first and last page numbers, month or week of issue, and year of publication. They should be arranged according to the order in which they are cited in the text, and not alphabetically. All references must be numbered consecutively.

Reprints

Contributors are ordinarily provided with 50 courtesy copies of the articles in the form of reprints. In cases of multiple authorship, additional copies will be provided for coauthors upon request.

XUM

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
WASHINGTON, D.C. 20201

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF H.E.W.

If you do not desire to continue receiving this publication, please CHECK HERE ☐; tear off this label and return it to the above address. Your name will then be promptly removed from the appropriate mailing list.